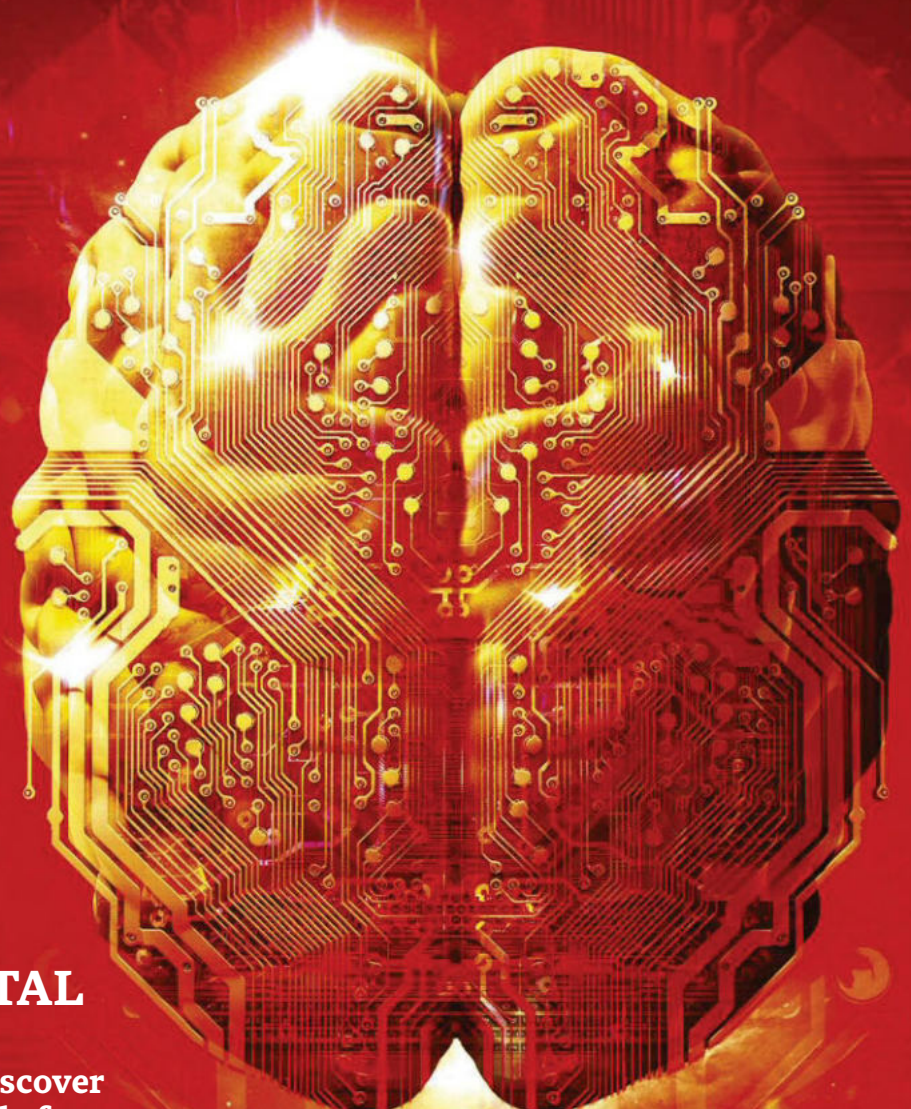
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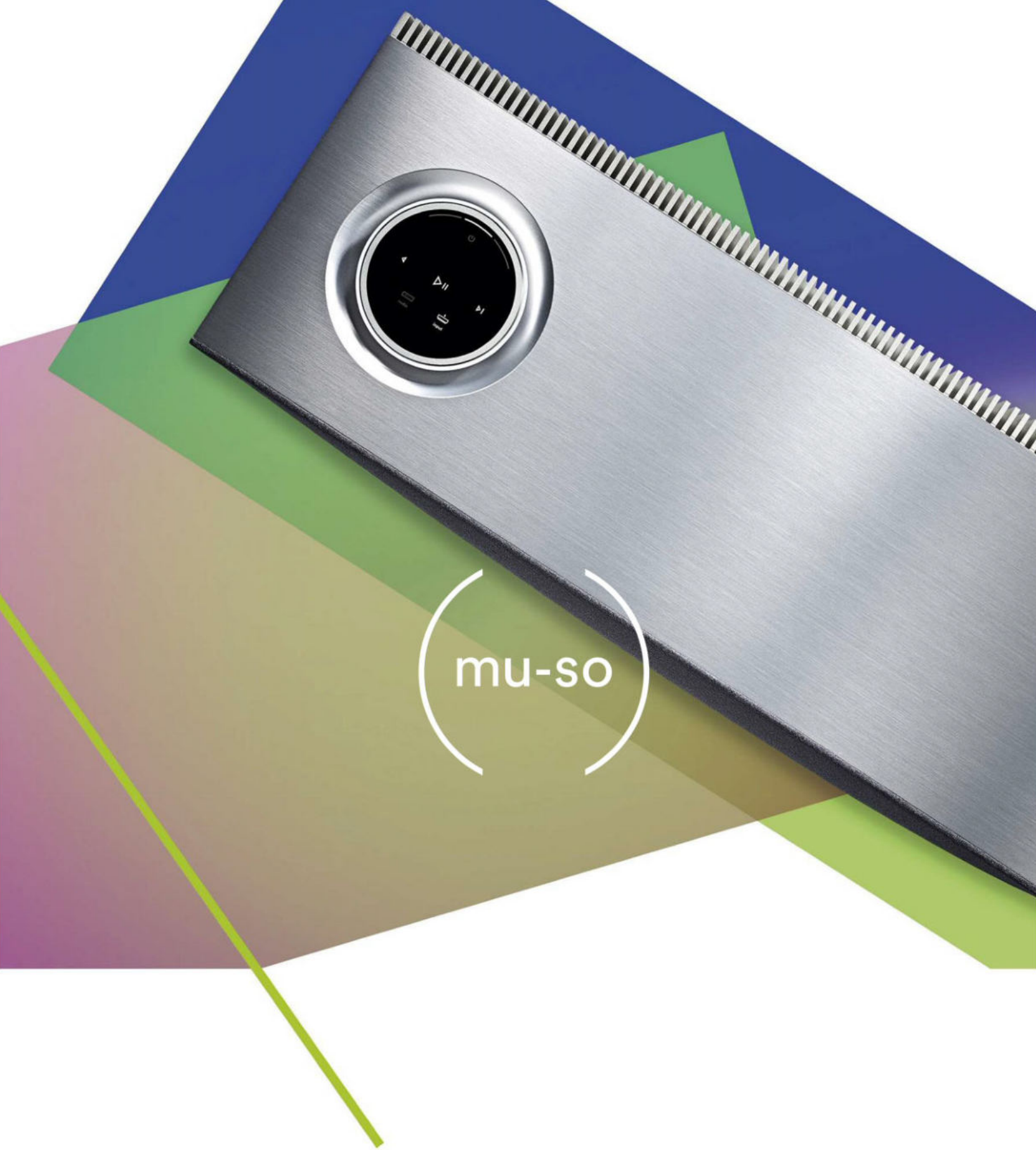




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Dogs don't feel guilty, they're just pretending → p60

WELCOME



The eagle-eyed among you might have noticed that this is our 300th issue. A quick back-of-the-envelope calculation tells me that I've worked on the magazine for almost 30 per cent of its life (that's 83 issues, just in case you're wondering).

So, in my time on the magazine, what have I learned? Off the top of my head: space smells like rotten eggs and astronauts can't burp aboard the International Space Station. Sea lions have the best rhythm in the animal kingdom and cows can predict earthquakes better than humans can. Water can be sticky *and* slippery and a good sneeze can travel up to eight metres away from the source. And finally, no one *really* knows what dark matter is.

I could go on, but I suspect many of you have been on this journey of discovery with me. So all I really want to say is thank you. Thank you to you, the tens of thousands of readers whose undying curiosity has driven you to buy our magazine and keep our post bags stuffed full of brilliant questions for the last 25 years. Without you, there would be no *BBC Focus*, so please get in touch and let us know what you think about the magazine and what you'd like to see us cover in the future. Here's to the next 300 issues!

Enjoy the issue.



Daniel Bennett, Editor

IN THIS ISSUE



DR JOHN BRADSHAW

John is a visiting fellow at the University of Bristol's School of Veterinary Sciences, where he studies cat and dog behaviour. This month, he finds out if our pet pooches can make us healthier and happier. → p56



JO CARLOWE

Freelance journalist Jo has a particular interest in health, psychology and well-being. In this issue, she takes a look at whether our modern addiction to technology could be meddling with our minds. → p38



DR DAVID HAMMOND

With conflict in Syria and Iraq, and terrorism in Europe, it can be depressing to turn on the news. But are we really getting more violent? War expert David explores the evidence. → p76

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A messy desk could be a sign that you're a creative genius → p112

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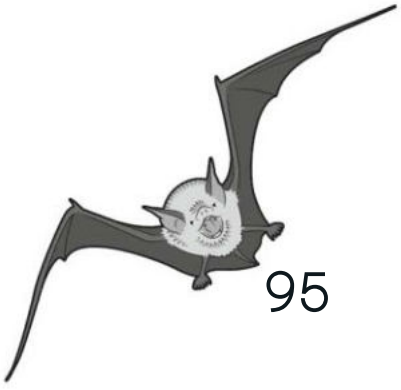
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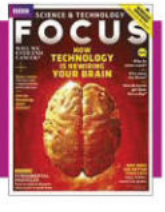
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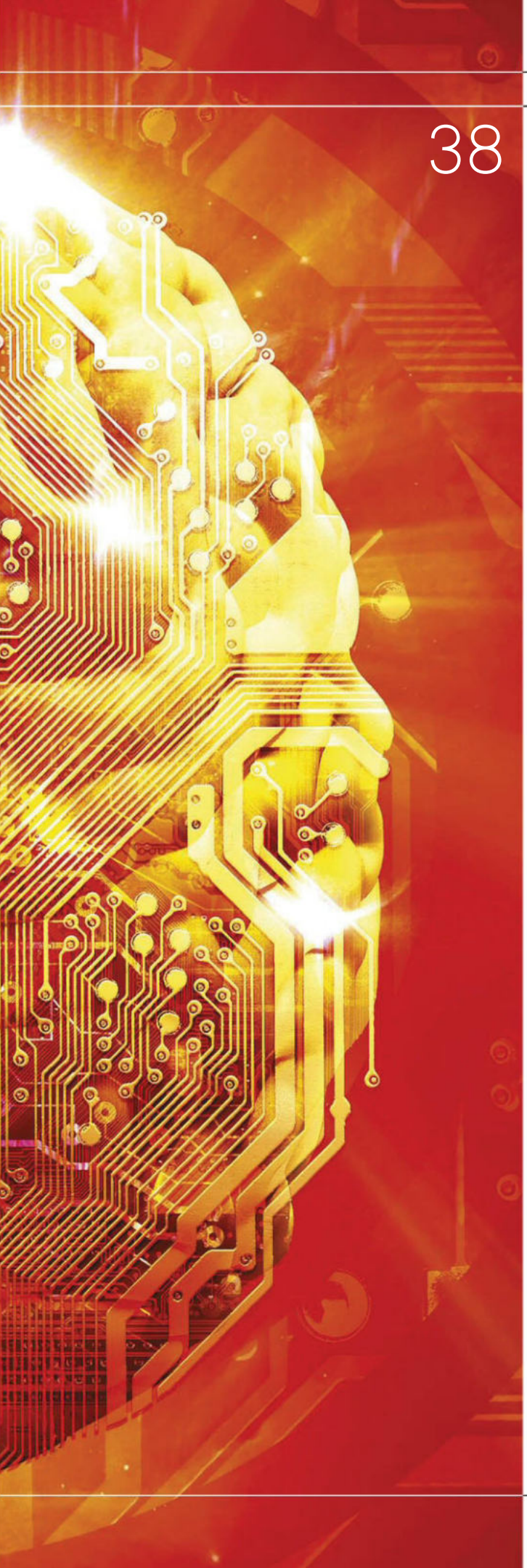
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EYE OPENER

Nothing to sniff at

MALANJE,
ANGOLA

A rat works hard in Angola, sniffing out landmines hidden beneath the soil. It is one of a team of 27 rats that have been trained by the company APOPO to help clear the land left riddled with mines by the recent civil war.

Weighing in at 1.5kg, the African giant pouched rat is too light to trigger a landmine, but can sniff them out with ease. They can detect tiny amounts of TNT, even when it's buried up to 20cm under the ground. It takes nine months and $8,000 to train a rat, but it's worth it. Each can cover 400 square metres a day, 15 times what an engineer equipped with a detector can manage.

"When the rat detects the smell of TNT, he or she will put their nose in the air or scratch at the ground, and that indicates they've found something in that particular area," says biologist and BBC presenter Patrick Aryee, who witnessed the rats at work as part of the recent series *Super Senses: The Secret Power Of Animals*. "The rat has a banana or a nut as a reward, then carries on going up and down."

The rats are a squeaking success, having detected thousands of mines from Angola to Mozambique and Cambodia.

PHOTO: JAY CABOZ





EYE OPENER

Scorched earth

CALIFORNIA,
USA

Dense, black smoke climbs above the trees in Wrightwood, California, following the Blue Cut wildfire. The blaze, the cause of which is unknown, raged for seven days before finally being contained on 22 August.

The flames scorched more than 150 square kilometres of forest, destroying over 300 homes and buildings, and forcing 82,000 residents to evacuate.

"The number, size and severity of fires in California have been increasing since the 1980s," says Mark Schwartz, associate director of the John Muir Institute of the Environment. "Headwaters Economics [an independent research company] estimates that the federal government now spends more than $3bn annually on wildfire."

The fire started after five consecutive days of red-flag warnings from the National Weather Service. These are issued during periods of high temperatures, low humidity and erratic winds – perfect conditions for small blazes to quickly spread.

"Increasing populations in and around the forests of California has led to an increase in the number of ignitions and the number of fires," Schwartz adds. "Most of our fires are caused by human ignitions."

PHOTO: GETTY



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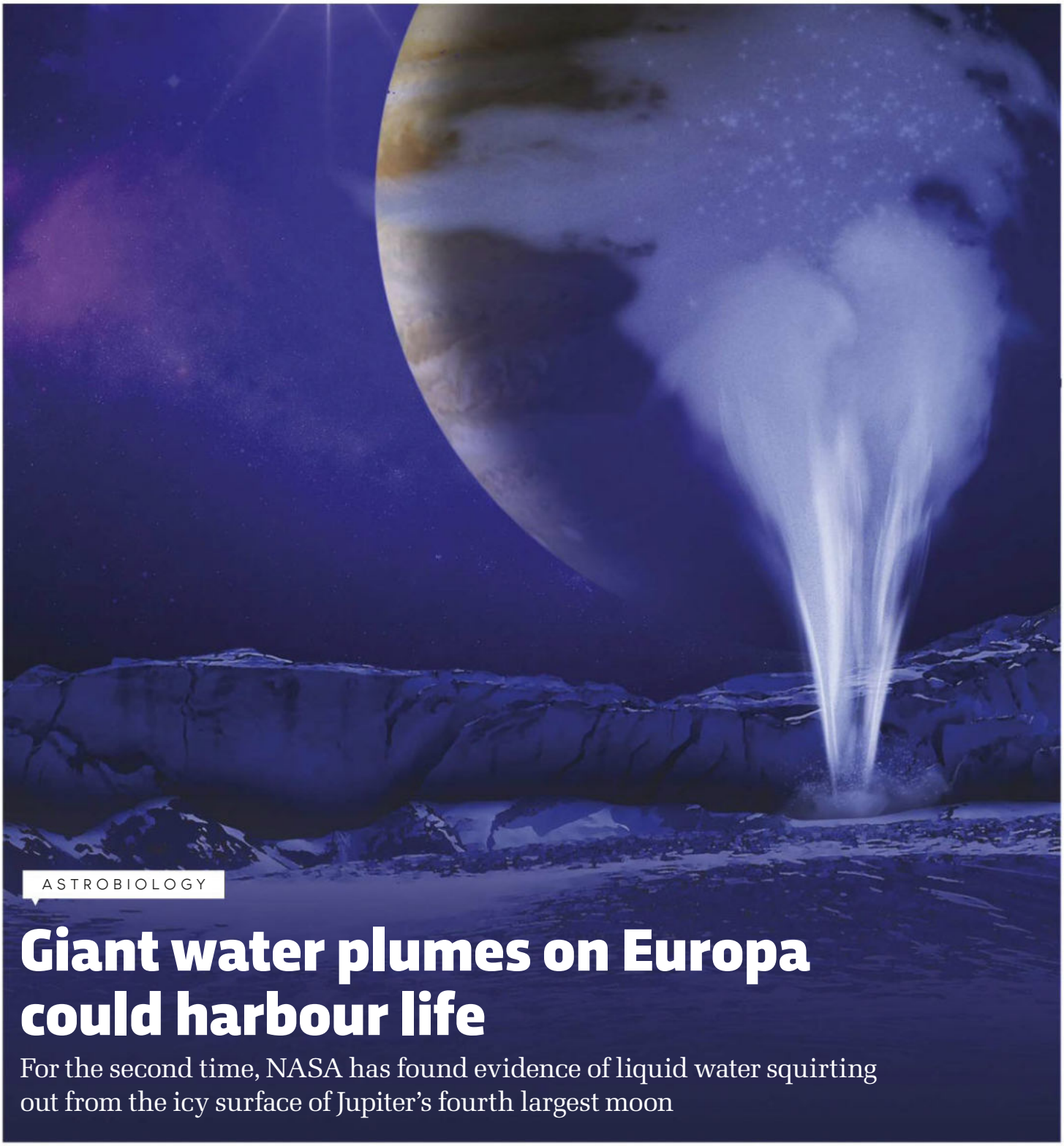
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DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

NOVEMBER 2016 | EDITED BY JASON GOODYER



ASTROBIOLOGY

Giant water plumes on Europa could harbour life

For the second time, NASA has found evidence of liquid water squirting out from the icy surface of Jupiter's fourth largest moon

PHOTO: NASA

If there's life in the Solar System anywhere other than here on Earth, then Jupiter's moon Europa may well be the best place to find it. Liquid water is thought to be one of the essential elements required for the existence of microbial life, and this icy satellite is believed to harbour a vast sea, twice the size of Earth's oceans, underneath its frozen, barren surface. The problem is, for a probe to be able to get into the water to search for signs of life it would first have to drill through miles of solid ice – no mean feat.

However, there may be another way. Astronomers using the Hubble Space Telescope have detected what they believe to be plumes of water vapour erupting from the moon's surface. This means a probe may be able to sample the content of the water during a flyby – a much simpler task.

"Europa's ocean is considered to be one of the most promising places that could potentially harbour life in the Solar System," said NASA's Geoff Yoder. "These plumes, if they do indeed exist, may provide another way to sample Europa's subsurface."

The team detected the wispy, finger-like emissions while searching for evidence of an atmosphere on the moon by training the telescope on it as it passed in front of its host planet.

"The atmosphere of an extrasolar planet blocks some of the starlight that is behind it," said researcher William Sparks. "If there is a thin atmosphere around Europa, it has the potential to block some of the light of Jupiter, and we could see it as a silhouette."

Over 15 months, the researchers made 10 observations, finding evidence of water vapour in three of them. The plumes are estimated to climb to about 200km above the surface before falling back down as rain. The findings echo those of an earlier team, also using Hubble, who found evidence of water vapour erupting from Europa's south polar region in 2012.

In the coming years, researchers could look to confirm the venting activity using the infrared vision of NASA's James Webb Space Telescope, which is set to launch in 2018.

"Hubble's unique capabilities enabled it to capture these plumes, once again demonstrating Hubble's ability to make observations it was never designed to make," said NASA's Paul Hertz. "This observation opens up a world of possibilities, and we look forward to future missions – such as the James Webb Space Telescope – to follow-up on this exciting discovery."

EUROPA IN NUMBERS

3.551 DAYS
ORBITAL PERIOD

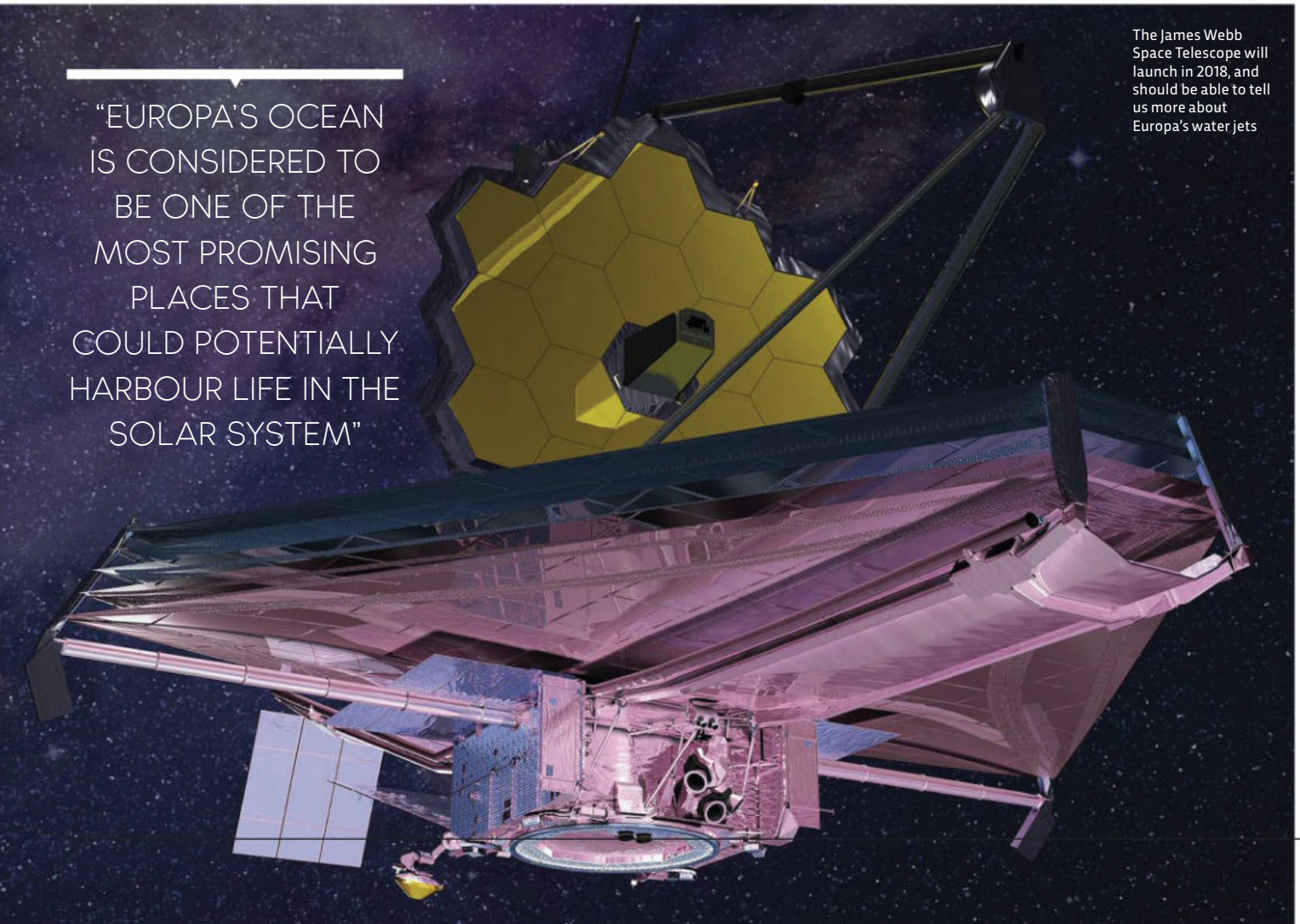
4.5 billion
YEARS OLD

3,100km
DIAMETER

780 million
KM FROM THE SUN

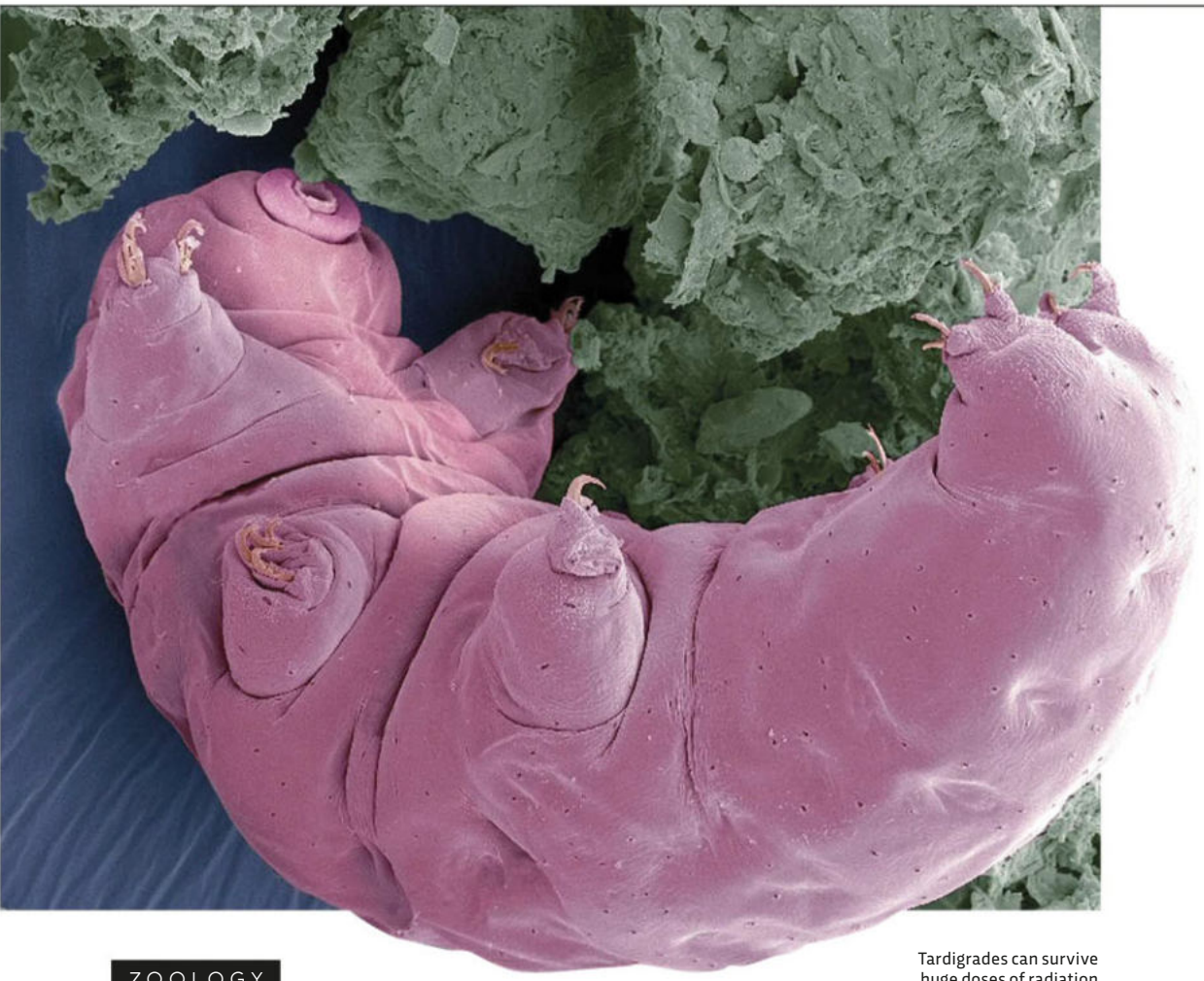
-172°C
MEAN SURFACE TEMPERATURE

"EUROPA'S OCEAN IS CONSIDERED TO BE ONE OF THE MOST PROMISING PLACES THAT COULD POTENTIALLY HARBOUR LIFE IN THE SOLAR SYSTEM"



The James Webb Space Telescope will launch in 2018, and should be able to tell us more about Europa's water jets

PHOTOS: NASA, GETTY



Tardigrades can survive huge doses of radiation – and now their secret has been revealed

ZOOLOGY

Tardigrade biology could protect humans from radiation

Tardigrades are seriously tough cookies. They can survive in environments with temperatures as high as 100°C and as low as –200°C, at pressures up to six times higher than the bottom of the ocean, and even in the vacuum of space.

Now, researchers at the University of Tokyo have figured out the secret behind another of their incredible skills – the ability to survive huge doses of radiation. It turns out it's all down to a special protein they've dubbed Dsup (damage suppressor).

After mapping the entire genome of the tardigrade Ramazzottius varieornatus, the team discovered that Dsup protects the animals' DNA from radiation damage.

Next, the team genetically engineered human kidney cells with the ability to create Dsup, and blasted them with radiation. The treated cells showed half the DNA damage when compared to untreated cells, and remained capable of reproducing.

"What's astonishing is that, previously, molecules that repair damaged DNA were thought to be important for tolerating radiation. On the contrary, Dsup works to minimise the harm inflicted on the DNA," said researcher Takuma Hashimoto.

"After exposing the cultured cells to X-rays, initially, we found only a small difference between those with and without Dsup," he continues. "However, we left them in the incubator for a while in the hope that a key property of Dsup lay hidden somewhere in that minuscule difference, and that the difference would eventually become quite distinct. To our great surprise, when we checked the cells under the microscope some time later, their shape and number had changed significantly."

The team believes that the tardigrade genome sequence may contain other Dsup-like proteins responsible for the animals' amazing toughness.

THE DOWNLOAD

FAST

What's that – a new fad diet, perhaps?
Don't be ridiculous. It's the Five-hundred-metre Aperture Spherical Radio Telescope, obviously.

Tell me more?
Well, as the name suggests, FAST is a 500m-wide radio telescope situated in the mountains of Guizhou Province, China. It cost £140m, took five years to build and is the biggest of its kind in the world. It came online in September.

Wow. So what will it do?
The primary, somewhat lofty goal of FAST is to investigate the evolution of the Universe. But it will also be looking for pulsars, the rotating remnants of dead stars – and for signals sent from intelligent extraterrestrial life.

When will we start seeing any results?
It's only in the test run stage at the moment, but FAST has already detected a pulsar 1,351 light-years away. It's as yet unclear when the telescope will be running at full capacity.



FAST is the biggest telescope of its kind in the world

SPACE

HUBBLE CAPTURES DEATH THROES OF DISTANT SUN

Is this what the end of the world will look like? This striking image shows the kaleidoscopic last hurrah of NGC 2440, a Sun-like star located 4,000 light-years from Earth.

The photo was taken by the Hubble Space Telescope and shows the burnt-out core of the star – the tiny white dot in the centre of the image, known as a white dwarf – surrounded by plumes of ejected gas. The material jettisoned by the star glows with different colours depending on its composition, its density and how close it is to the hot centre: helium glows blue, oxygen blue-green, and nitrogen and hydrogen red.

With a surface temperature of more than 200,000°C, NGC 2440's white dwarf is one of the hottest ever discovered, while the two distinct lobes of gas surrounding the core suggest that the star must have previously shed its mass in at least two separate outbursts.

The Universe is littered with these stellar relics, which were mistakenly dubbed planetary nebulae by William Herschel after their discovery in the 18th Century. Our Sun will also ultimately share the same fate. But don't worry too much – that won't happen for another five billion years.

WITH A SURFACE TEMPERATURE OF MORE THAN 200,000°C, NGC 2440'S WHITE DWARF IS ONE OF THE HOTTEST EVER DISCOVERED



ANTHROPOLOGY

ALL NON-AFRICANS CAN BE TRACED BACK TO A SINGLE ANCIENT MASS MIGRATION

Sometime around 75,000 years ago, the human race seems to have really caught the travel bug. A worldwide DNA study has found genetic evidence which suggests that a single mass migration event, beginning in Africa, was responsible for the population of the rest of the globe.

The study analysed the genomes of almost 800 people drawn from hundreds of small indigenous populations to piece together the most diverse genetic dataset ever.

A team at Harvard Medical School sequenced samples from 142 small populations, most of which were previously understudied, including a number of Native American and South Asian populations. By matching up various bits of common DNA, they concluded that the vast majority of modern human ancestry in non-Africans comes from a single population that migrated out of Africa.

"As humans, we are not just the people who live in industrialised countries, and we are not just the people who live in numerically large groups," said researcher David Reich. "If we want to understand who we really are, we have to realise that some of the most interesting aspects of human variation are only present in under-represented, small populations."

Another team, led by Danish researcher Eske Willerslev, sequenced the complete genetic information of 83 Aboriginal Australians, as well as 25 Papuans from New Guinea. Using similar DNA matching techniques, they concluded that the overwhelming majority of the genomes of non-Africans alive today stem from one ancestral group of migrants that left Africa around 72,000 years ago.

"The study addresses a number of fundamental questions about human evolution: how many times did we leave Africa, when was Australia populated, and what is the diversity of people in and outside Australia?" said lead researcher Eske Willerslev. "Technologically and politically, it has not really been possible to answer those questions until now. We found evidence that there was only really one wave of humans who gave rise to all present-day non-Africans, including Australians."



Aboriginal Australians were one of many indigenous populations whose DNA was studied in the Harvard research

PHOTO: NASA/HUBBLE, PREBEN HJORT/MAYDAY FILM

IN NUMBERS

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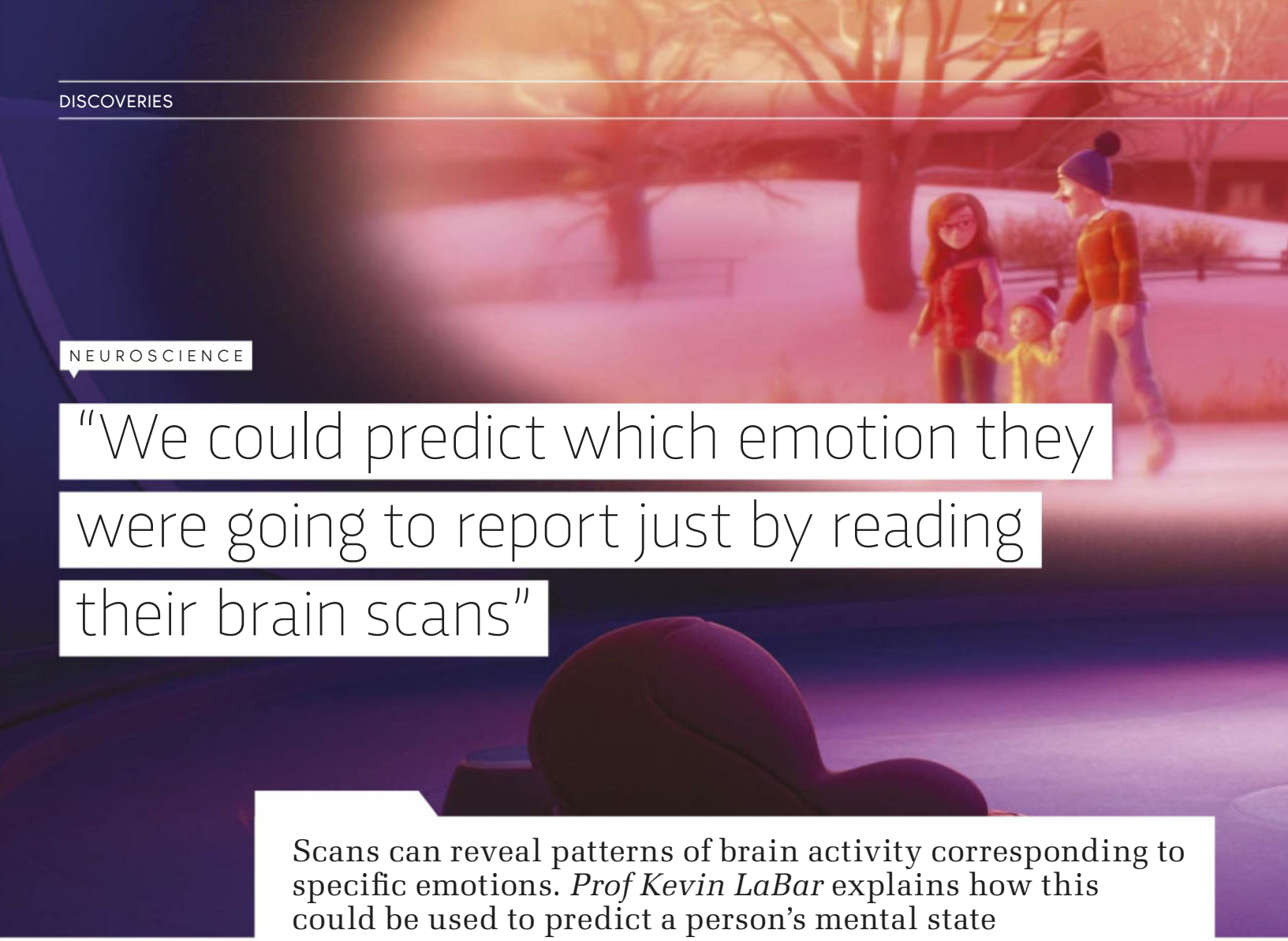
The number of different species of giraffe found to exist by a genetic analysis carried out by German researchers. All giraffes were previously thought to belong to the same species.

10%

The amount of the Earth's wilderness that has vanished in the past two decades, according to figures released by the World Conservation Society. South America and Africa are the worst hit, they say.

800

The number of children estimated to have been fathered by Diego, a 100-year-old *Chelonoidis hoodensis* tortoise living on Española in the Galapagos Islands. With just 2,000 animals left, Diego has certainly done his bit to keep his species alive.



NEUROSCIENCE

"We could predict which emotion they were going to report just by reading their brain scans"

Scans can reveal patterns of brain activity corresponding to specific emotions. *Prof Kevin LaBar* explains how this could be used to predict a person's mental state

Why scan the brain for emotions?
Other than asking people how they feel, we don't have good objective markers of emotions, and so researchers have been trying to use brain imaging. The first way we tackled this problem was to induce specific emotions in people using film clips and music, then train a computer algorithm to distinguish each emotion. We're using machine learning methods, so we train the computer on 25 per cent of the data, then it learns and tries to predict [emotions] on the other 75 per cent.

Which regions control emotions?
In the prefrontal cortex [the area at the front of the brain], there was one region that was fairly common, but the patterns of brain activity were actually quite distinct everywhere else. Of course, we set up the computer algorithm to detect differences, so it didn't analyse places that were common. In the rest of the brain, there was some overlap at the basic level, like the temporal or parietal lobes [the areas in the top and middle of the brain], but specific patterns were unique.



RIGHT: Brain patterns showing different emotional states. Top row: contentment, amusement, surprise. Bottom row: fear, anger, sadness, neutral

How did you create a map of emotions?
We looked for evidence of those patterns while 21 people were resting in a scanner, taking these as examples of spontaneous elicitation of emotion by whatever mind-wandering was going on while they rested. We got them to report on their emotions every 30 seconds, and could predict which emotion they were going to report just by reading their brain scans in the previous 10 seconds.

In a larger group of 499 subjects, we asked them at the end to reflect on how anxious they felt during the scan. We found that the extent to which the 'fear' pattern emerged predicted how anxious they felt later, and how often the 'sad' marker appeared predicted how depressed they reported feeling. This is an exciting development because it's an aspect of emotional experience we've never been able to quantify in any way.

PHOTOS: REX ILLUSTRATION: RAJA LOCKEY



ABOVE: Pixar movie *Inside Out* shows different emotions as a set of discrete characters, but the real picture is more complex

Pixar's *Inside Out* was lauded by psychologists for its successful portrayal of emotions. So did you find that emotions matched Pixar's characters?
Unfortunately we didn't colour-code our map to match the colours of the characters in that film! In the film there was one controller for each emotion, and here it's a distributed pattern spread across the brain. We had fear, anger, sadness, surprise, amusement, contentment and a neutral state. So we had a good span of emotions. Also, it depended on what you can induce with music and film clips – there are some emotions, like envy or pride, that are hard to elicit with music, for example.

Why are brain scans useful?
One of the key ways in which this research can be applied is in new outcome measures for clinical interventions. So if you're testing a drug or a behavioural therapy for depression, and you really wanted to treat the sadness component of that depression, it can be useful as a marker for change. A person might report feeling somewhat better, but if we see evidence in the brain that this 'sad' marker is still present during the resting state, then that suggests this person may be vulnerable to relapse later on.



WANNABE SUPERHEROES

Think Superman's disguise is a bit naff? It turns out that just donning (or removing) a pair of glasses can reduce your chance of being recognised by 6 per cent, according to researchers at the University of York.

TALL PEOPLE

Lanky people are better at judging spatial relationships than their more vertically challenged counterparts, say researchers at the Ohio State University. But don't get your stilts out yet: the results held even when the taller test subjects sat down.

GOOD MONTH

BAD MONTH

DORMICE

The Mad Hatter's tea party could be losing a guest. Numbers of the UK's native hazel dormouse have declined by over a third since 2000, says the People's Trust for Endangered Species, making it vulnerable to extinction.

WOMEN

Need another 40 winks, ladies? You're not alone – scientists at McGill University have found that women are more prone to sleep disturbances than men. Their body clocks are shifted, so they feel tired two hours earlier and wake up earlier.





Scientists have created a realistic model of *Psittacosaurus* using skin pigment information found in a fossil specimen

PALAEONTOLOGY

UNIQUE FOSSIL INSPIRES MOST ACCURATE MODEL OF A DINOSAUR EVER

Long before Pikachu and co were even a twinkle in their creator's eye, this cute little Pokemon-style dinosaur could be found scurrying around in the forests of China.

Dubbed *Psittacosaurus*, meaning 'parrot lizard', thanks to its distinctive hooked beak, the small, turkey-sized beastie lived in the early Cretaceous period around 120 million years ago. Now, using an incredibly well-preserved fossil specimen displayed in Senckenberg Museum, Frankfurt, researchers from the University of Bristol and palaeoartist Bob Nicholls have created the most accurate, life-sized model of a dinosaur ever.

Key to the project were small structures preserved in the skin of the fossil called melanosomes. These carry melanin pigments, which are what give feathers and skin their colour. From these pigments, the team could determine that the dinosaur sported a common camouflage pattern known as countershading, meaning the skin is darker on top than on the underside.

"WE NOW HAVE THE BEST SUGGESTION AS TO WHAT THIS DINOSAUR WOULD REALLY HAVE LOOKED LIKE"

"Our *Psittacosaurus* was reconstructed from the inside-out. There are thousands of scales, all different shapes and sizes, and many of them are only partially pigmented," said Nicholls. "It was a painstaking process but we now have the best suggestion as to what this dinosaur would really have looked like."

Furthermore, by photographing their model in the Cretaceous plant section of the Bristol Botanic Garden and analysing the effectiveness of the camouflage, the team was able to determine where the animal was likely to have lived.

"We predicted that the *Psittacosaurus* must have lived in a forest. This demonstrates that fossil colour patterns can provide not only a better picture of what extinct animals looked like, but they can also give new clues about extinct ecologies and habitats," said researcher Jakob Vinther. "We were amazed to see how well these colour patterns actually worked to camouflage this little dinosaur."

PHOTOS: JAKOB VINTHER/UNIVERSITY OF BRISTOL/BOB NICHOLLS, NASA X2. ILLUSTRATION: RAJA LOCKEY

SPACE

NASA'S JUNO BEAMS BACK FIRST PICTURES OF JUPITER

Showing gigantic raging storms, vast swirling auroras and dense layers of cloud, these incredible photos reveal the surface of Jupiter in hitherto unprecedented detail.

The snaps were taken by instruments onboard NASA's Juno spacecraft during its first-ever flyby of the Solar System's largest planet.

"It looks like nothing we have seen or imagined before," said Juno's principal investigator, Scott J Bolton. "It's bluer in colour up there than other parts of the planet, and there are a lot of storms. There is no sign of the latitudinal bands or zone and belts that we are used to – in fact, this image is hardly recognisable as Jupiter. We're seeing signs that the clouds have shadows, possibly indicating that the clouds are at a higher altitude than other features."

Juno completed its five-year journey to Jupiter in July and has started beaming back data from its eight instruments, following its first successful six-hour transit around the planet. The craft was able to get within 4,300km (2,700 miles) of the planet's churning clouds – the closet flyby ever.

Images snapped by the Jovian Infrared Auroral Mapper (JIRAM) show the first ever infrared close-ups of the planet's violent southern aurora.

"JIRAM is getting under Jupiter's skin, giving us our first infrared close-ups of the planet," said another Juno researcher, Alberto Adriani. "These first infrared views of Jupiter's north and south poles are revealing warm and hot spots that have never been seen before. And while we knew that the first-ever infrared views of Jupiter's south pole could reveal the planet's southern aurora, we were amazed to see it for the first time."

Juno is scheduled to complete a further 36 flybys before finally plummeting to the planet's surface in February 2018.



The first pictures sent back by NASA's Juno spacecraft are revealing Jupiter's surface in greater detail than ever before. The inset image here is in infrared

THEY DID WHAT?!

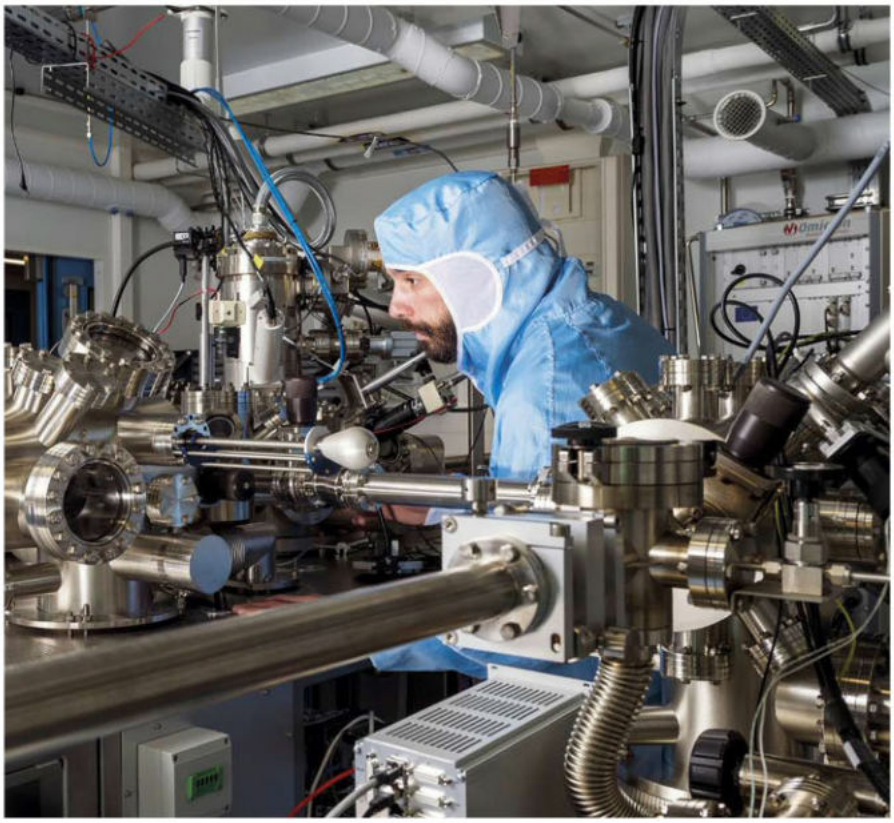


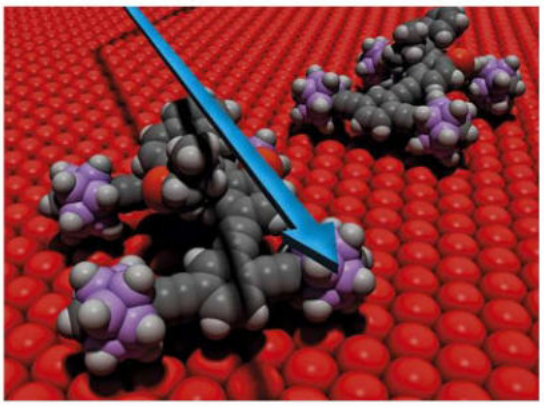
MONKEYS TAUGHT TO TYPE SHAKESPEARE USING THEIR THOUGHTS

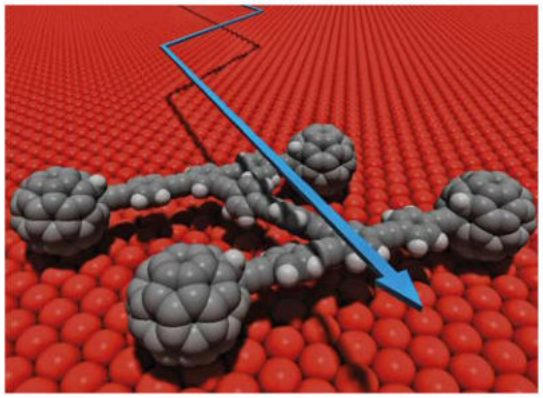
What did they do?
Using Rhesus macaques that had previously been taught to recognise text characters and point to them on a screen, a team of neuroscientists implanted signal-reading electrodes directly into the region of the monkeys' brains that controls hand and arm movements. By running the signals through software that translated them into the movement of a cursor around a keyboard displayed on a computer monitor, they were able to get the monkeys to copy passages of text from Shakespeare's *Hamlet*.

What did they find?
After extensive training, the macaques were able to transcribe the text at speeds of up to 12 words per minute.

Why did they do that?
The researchers are developing the technology for eventual use by human patient who have difficulty in communicating due to disability or injury.







NANOTECH

MINIATURISED WACKY RACES

Forget Formula 1 – cars the size of molecules are coming to France to race on a track made of gold. *Rob Banino* sizes up the competition

People will race anything, given half a chance. Whether it's motorcars, mammals or lawnmowers, we want to know which is the fastest. A race is also what's bringing an international group of scientists to Toulouse, France on 14 October – but they're coming to race molecules. Molecules that have been engineered to be tiny nanocars.

"A nanocar is a special kind of nano-vehicle," explains Dr Christian Joachim of the Centre National de la Recherche Scientifique in Toulouse, the nanocar race director. "They're made of four molecular wheels, a molecular chassis and [in some cases] a molecular motor. All these chemical-mechanical parts are bonded together to form a single, robust molecule."

Needless to say, a molecule that's been engineered to drive across an atomic landscape is small – very small. "Wheel diameter is generally less than one nanometre and a chassis is about two to three nanometres long," says Joachim. One nanometre is one billionth of a metre; the average human hair is about 25,000 nanometres wide.

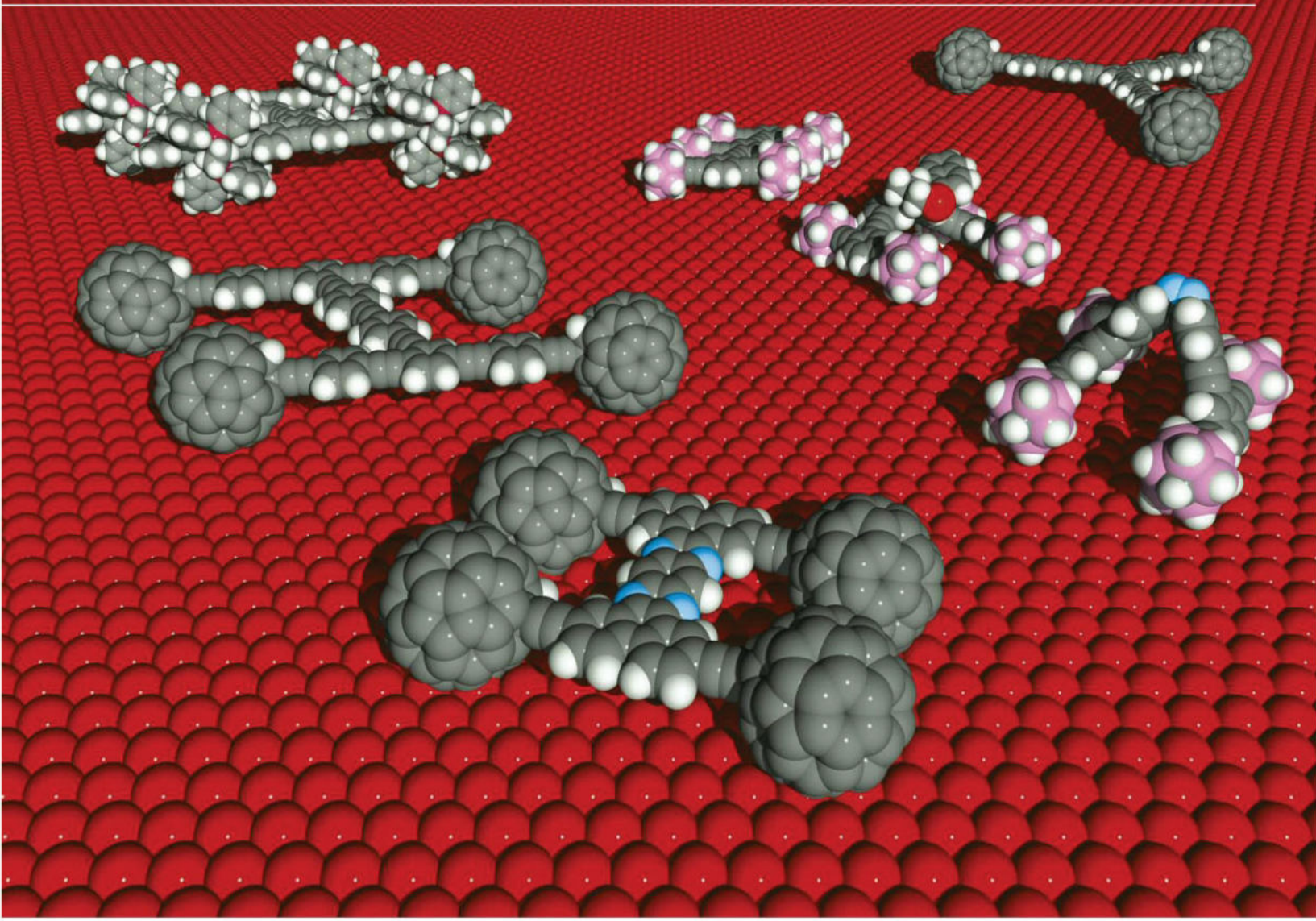
"AFTER EACH SEGMENT, WE'LL TAKE AN IMAGE TO CONFIRM THE NEW LOCATION OF THE NANOCAR... THEN DRIVE IT AGAIN"

Dealing with something that small obviously presents challenges, the biggest of which is actually seeing the cars. But before the cars can be seen, they need to be built. And these tiny cars are made in huge numbers. "We make the cars much like you'd build a pharmaceutical material, with a step-by-step synthetic procedure," says Prof James Tour, a co-leader of one of the five teams taking part in the race. "But we don't make one at a time, we make a trillion billion at a time."

Their size and the number cause more problems when it comes to getting them on the track. "You have to have enough nanocars to be able to find one, but if you have too many it becomes like a parking lot and none of them can move," Tour points out. "Getting that balance between too few and too many isn't easy to do."

As for the track, it may be small – about 100nm, long with two 45° turns – but more thought has gone into its construction than even the most extravagant Formula 1 circuit. For one thing, it's had to be made of gold.

PHOTOS: JAMES TOUR/RICE UNIVERSITY



"It's made of gold because the molecules of the nanocars won't be chemically transformed when they come into contact with it," says Joachim. But it's not just because gold is the least reactive metal, it's also because it can be made atomically flat. And being flat is important because when your car's the size of a single molecule, even the smallest bump becomes a mountain.

Motorised nanocars do exist, but aren't permitted in this race. Instead the cars will be powered by a scanning tunnelling microscope (STM), a device that can image individual atoms by passing an electrically charged tip over the surface of a sample. "What drives the cars for this race will be the electric field gradient induced by the tip of the STM," explains Tour. "The tip moves and the nanocar follows the tip… it's akin to the way a balloon is drawn towards your hand if you build up a sufficient static charge."

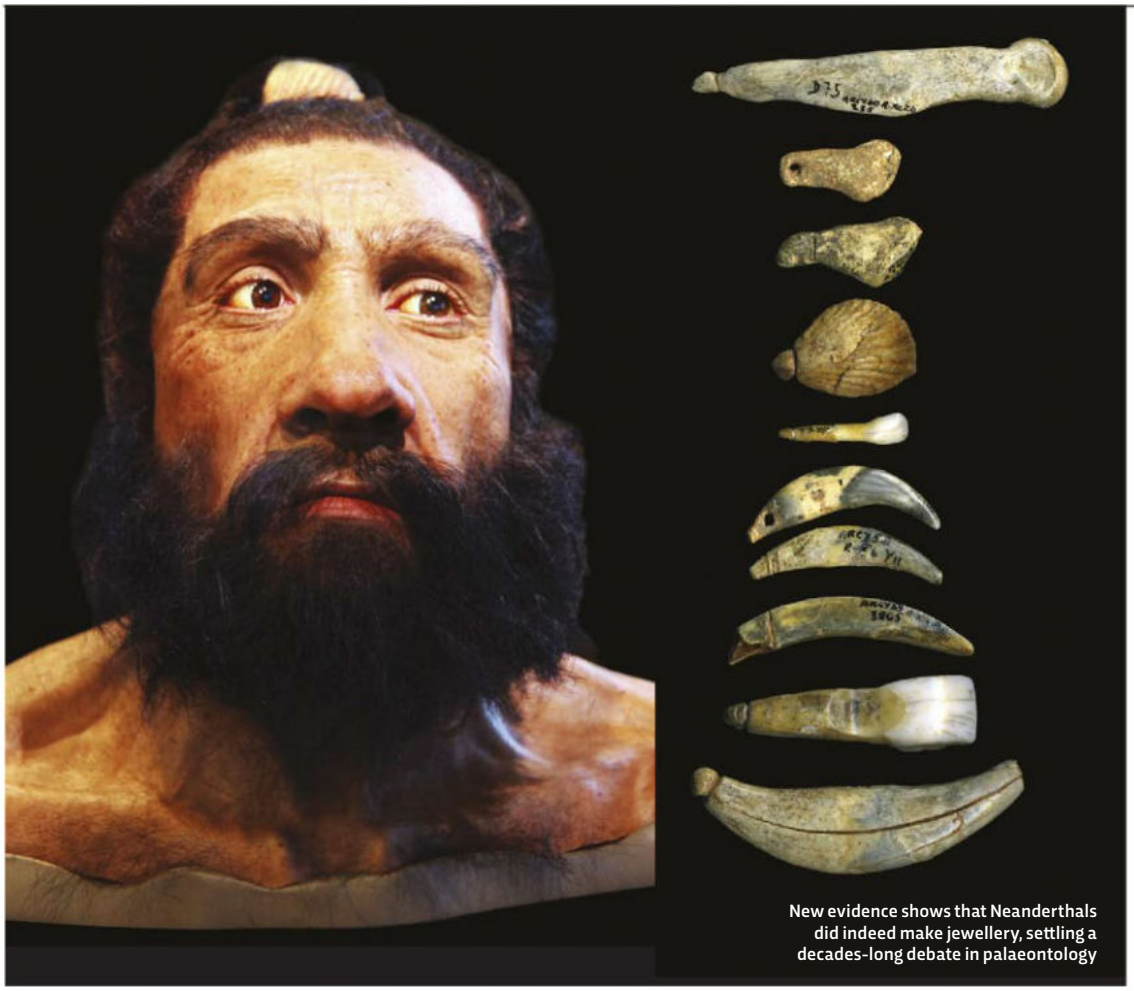
Using the scanning tunnelling microscope has another advantage: it can also be used to image the tiny nanocars themselves.

"When we're actually driving the cars, we can't image them," explains Prof Saw-Wai Hla, co-leader of the Ohio University Team. "After driving each segment, we'll take an image to confirm the new location of the nanocar… then we can drive it again. So there'll be a sequence of driving and imaging until we reach the finish line." This image-drive-image-drive sequence means although the race is over a minuscule distance, it could take up to 38 hours to complete.

Although it undisputedly sounds like great fun, the race does have a serious side. In the short term, it's hoped that the competition could lead to better nano-imaging technologies and manipulation of nano-scale objects. But in the long term, according to Joachim, nano-machinery "could be of great use in the atom-by-atom deconstruction of our industrial and urban waste or in capturing energy."

Given what's at stake, the scientists involved are taking it very seriously. But of course, they also want to find out whose molecule is the fastest – as we said, that's just human nature.

ABOVE: You could fit around 8,000 of these tiny racing cars, end-to-end, across the width of a single human hair



New evidence shows that Neanderthals did indeed make jewellery, settling a decades-long debate in palaeontology

ANTHROPOLOGY

WERE NEANDERTHALS THE ORIGINAL HIPSTERS?

We've already had the paleo diet, but could paleo jewellery be the next big hipster trend? A team from the University of York has found that Neanderthals crafted necklaces and other items of jewellery using animal teeth, shells and ivory. Such behaviour was previously thought to be exclusive to humans.

In the late 1940s a large collection of hominin remains were found surrounded by intricate body ornaments and jewellery in the Grotte du Renne in Arcy-sur-Cure, central France. Over the intervening decades, debate has raged among palaeontologists as to whether Neanderthals would have been capable of the complex, symbolic thought processes required to produce such decorative items.

Now, by analysing the proteins of some of the previously unidentified hominin specimens, the researchers from York were able to determine the remains most likely belonged to a Neanderthal infant. And radio carbon dating shows that the sample is around 42,000 years old. This puts it near the end of the Pleistocene epoch, which ranged from 1.8 million to around 11,000 years ago – a perfect match for the date of the artifacts which can now be assumed to have indeed been the work of Neanderthal jewellery-makers.

As interesting as that is, it's perhaps the protein analysis technique involved that's the real story here. "For the first time, this research demonstrates the effectiveness of recent developments in ancient protein amino acid analysis and radiocarbon dating to discriminate between Late Pleistocene clades," said researcher Matthew Collins. "These methods open up new avenues of research into contexts where hominin remains are scarce and where the biological nature of remains is unclear due to DNA not being preserved. This is of direct relevance to our understanding of hominin evolution."

WHAT WE LEARNED THIS MONTH

DOGS CAN UNDERSTAND US

"Who's a good boy? You are, yes, you *are*". A Hungarian study has found that pooches use the left hemisphere of their brain to understand the meaning of words and the right to understand their tone – just like humans do.

WE HAVE A SIXTH TASTE

There's nothing like tucking into a nice chip butty, right? Well, researchers at Oregon State University have found that our love for carb-rich foods could be due to the existence of a sixth flavour, dubbed 'starchy'.

GIANT PANDAS ARE NO LONGER ENDANGERED

Contrary to the black and white bears' reputation of having a blasé attitude towards the continued existence of their species, researchers have found giant panda numbers in southern China actually increased from 1,596 in 2004 to 1,864 in 2014. This means the animal is now classed as 'vulnerable' rather than 'endangered'.

THE MOON CAN TRIGGER EARTHQUAKES

Large-scale quakes are more likely to occur during full and new Moons, researchers in Japan have found. The effect is due to the pull of the Moon's gravity being stronger at these times, putting extra stress on the Earth's tectonic plates.

PHOTOS: DR MARIAN VANHEREN, TIM EVANSON/WIKIPEDIA

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You will commence your journey in Southampton where you'll board the majestic Queen Mary 2. A spectacular ship whose very essence, from grand design to final flourishes, harks back to the grand old ocean liners of the golden age of travel.

Approaching New York at dawn, you'll sail under the Verrazano Bridge. The deck of Queen Mary 2 hosts the perfect vantage point to enjoy an awe - inspiring golden sunrise emerging behind the Manhattan skyline and the iconic statue of liberty that heralds your arrival into the city that never sleeps. You'll be driven to your hotel where you'll spend two nights absorbing all that this unforgettable city has to offer before journeying to Philadelphia via private coach where you'll visit an authentic Amish farmhouse for lunch. Following an overnight stay in Philadelphia, you'll continue your journey to Washington DC, where you'll spend two nights and be taken on a guided tour of the city's highlights.

Next you'll begin your journey towards the pinnacle point of your voyage, the thunderous force that is Niagara Falls. During your two night stay in Niagara, you'll get to journey behind the falls and explore the region before returning home to the UK.

Your holiday includes:

- ✓ 7 night full-board cruise on board Queen Mary 2
- ✓ FREE outside to balcony upgrade
- ✓ 8 day tour from New York to Niagara Falls including a 2 night hotel stay in New York, 1 night hotel stay in Philadelphia, 2 night hotel stay in Washington DC and 2 night hotel stay in Niagara Falls
- ✓ Tour of Philadelphia including Independence Hall, the Liberty Bell and Rocky Steps at Philadelphia Museum of Art
- ✓ Tour of an Amish community including lunch
- ✓ Tour of Washington DC including The Lincoln Memorial and the National Mall
- ✓ Stop at Finger Lakes for wine tasting
- ✓ Hornblower sightseeing cruise and visit to Niagara-on-the-Lake
- ✓ Inbound flight and transfers

PRICES PER PERSON FROM

2017	Inside	Outside	Balcony	Grill Suite
May	£2,499	£2,899	£2,899	£4,399
Jun	£2,499	£2,899	£2,899	£4,199
Jul	£2,399	£2,799	£2,799	£3,999
Aug	£2,399	£2,799	£2,799	£3,999
Sep	£2,499	£2,899	£2,899	£4,199
Oct	£2,299	£2,699	£2,699	£3,799
Nov	£1,899*	£2,299	£2,299	£3,499

FREE OUTSIDE TO BALCONY UPGRADE

New York



Washington DC



*Price based on 5 November 2017 departure date.

Discover NIAGARA FALLS

Falling like a great curtain dividing America and Canada, Niagara Falls is a natural wonder to behold.

Thousands of people gather around every day, mist drenching their faces to watch the 150,000 icy gallons of water rush down the 1,000 foot drop. As part of your package you'll enjoy a journey behind the falls or a Niagara cruise, so you can get as close as possible to this natural spectacle.



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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

NOVEMBER 2016

EDITED BY RUSSELL DEEKS



PHOTO: MERCEDES-BENZ

ELECTRIC DREAMS

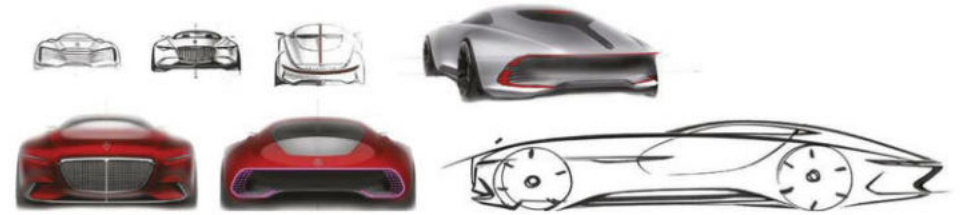
Could Mercedes give Tesla something to worry about?

Seen here is a concept all-electric coupé from Mercedes-Benz called the Vision Mercedes-Maybach 6. It's one of several electric vehicles that Mercedes and parent company Daimler have in the pipeline for launch over the next few years.

In May, Mercedes said that it would be launching four electric vehicles (two saloons and two SUVs) over the coming years. Yet more recently Reuters reported that, according to an unnamed internal source, the figure could be at least six, and possibly as many as nine. Obviously, given that this is coming from the rumour mill and not official sources, details are patchy, but it's been suggested that these will include at least one hybrid SUV ▶



Let's hope the heads-up display encourages Mercedes drivers to use their indicators...



with both an electric motor and a hydrogen fuel cell, expanding the car's range without needing to resort to dirty ol' gasoline.

That's as much as we know on that front, but in the meantime we *can* tell you a bit more about the Mercedes-Maybach pictured here. The concept was displayed at the recent Monterey Car Week show in California. It's an all-wheel drive machine, with four electric motors that produce 550kW of power and 738hp. These are backed up by a battery hidden within the floor that'll provide an additional 80kWh when needed. The Mercedes-Maybach can do 0-100km/h in under four seconds, has a top speed of 250km/h (155mph), and manages 500km (310 miles) on a single charge. It's quick to recharge, too, taking on enough juice for a 100km journey in just five minutes.

The lean and low design with its long bonnet pays homage to classic coupés of the past, while gullwing doors and a heads-up display projected onto the windscreen ensure the car looks thoroughly modern at the same time. And speaking of the technology inside the vehicle, Mercedes recently announced that it's teaming up with Microsoft on a project called In Car Office. This will integrate Microsoft Exchange with the operating system of your car's onboard computer, so that the car itself becomes a kind of four-wheeled personal assistant – automatically calculating the optimal route to a business meeting, or making hands-free calls to clients and customers. In Car Office is said to be on track to arrive in production vehicles early next year, so you can pretty much guarantee you'll find it inside the Mercedes-Maybach when it does eventually land in showrooms.

LUXURY AUTOMOBILE MANUFACTURERS ARE TAKING ELECTRIC CARS VERY SERIOUSLY INDEED

This strong push by Daimler/Mercedes into the electric vehicle sector is further evidence that luxury automobile manufacturers are taking electric cars very seriously indeed, posing a potential threat to Tesla's long-standing dominance of the sector. But Tesla's not sitting on its hands either: the company recently announced a new 100kWh battery pack for its Model S and Model X cars that founder Elon Musk described as "a profound milestone". A high-end Model S equipped with the new battery would, he said, be the fastest-accelerating mass production car on the market, capable of doing 0-100km/h in just 2.5 seconds. Wheeeeee!

NEWS BYTES



A £50 4G SMARTPHONE

Samsung has launched a smartphone based on the open-source Tizen operating system. The 4G device costs around £51 and has a four-inch AMOLED screen and a 5MP camera, but you need to be in India to get one...

A ROBOT WRITES (FROM RIO)

The Olympics saw an AI called Xiaomingbot generate some 450 sports reports, for publication on Chinese news outlet Toutiao. *The Washington Post* also experimented with AI 'journalism' at the Olympics.

UNCLE SAM NEEDS YOU!

The US Department of Defense is looking to create a better biohazard suit, and it's opened up the quest to public submissions – with $250,000 in prizes for anyone whose ideas make it to the finished suit.

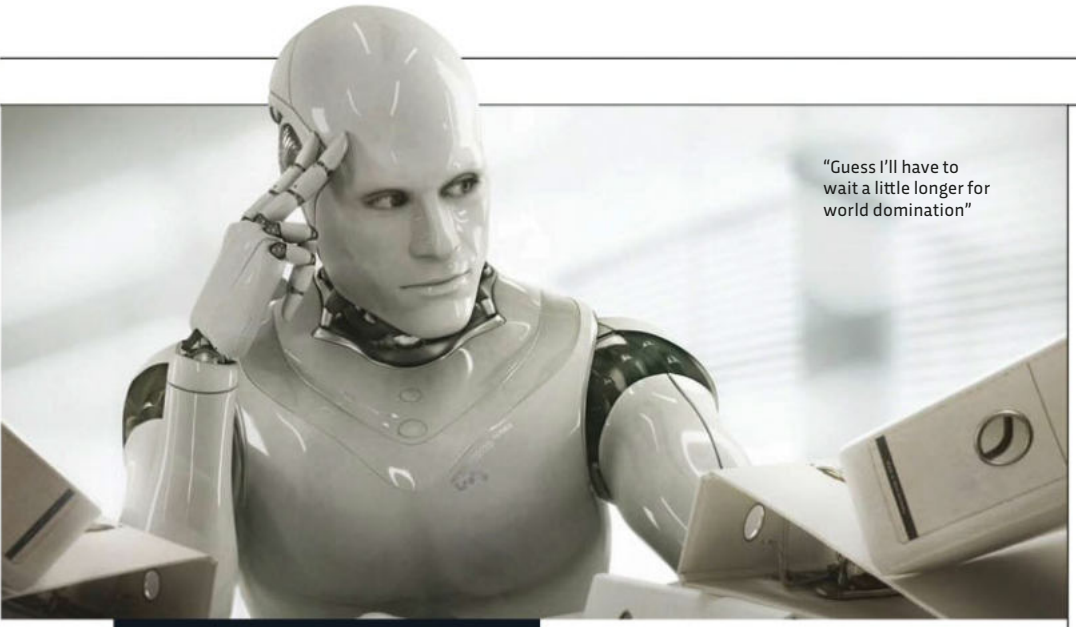


TIMBERRRRR!

Limberjack is a new VR app for the HTC Vive headset that lets you experience the thrills of 'limbing'; that is, chopping branches off trees with a chainsaw. Funnily enough, it's been developed by chainsaw maker Husqvarna rather than a games studio...

TALKING MOTORBIKES

Kawasaki is building a voice-controlled AI system for use in its future motorcycles. The Kanjo Engine will let you live out all your *Knight Rider* fantasies, albeit only on two wheels, from a currently unspecified date.



"Guess I'll have to wait a little longer for world domination"

ARTIFICIAL INTELLIGENCE

Tech giants form AI ethics 'committee'

Representatives from Google, Facebook, Microsoft, IBM and Amazon will join forces as a new industry body that will develop an ethical framework for AI research. The aim is to prevent us, as a species, from shooting ourselves in the foot by blindly adopting potentially harmful technologies.

The great advances made in the fields of artificial intelligence and robotics promise many benefits, but many of those most closely involved have long argued that some degree of regulation would be a good thing. Last year, for instance, Stephen Hawking, Elon Musk, Steve Wozniak and the *Journal Of Artificial Intelligence Research* editor Dan Roth were among the signatories of an open letter that read in part, "Because of the great potential of AI, it is important to research how to reap its benefits while avoiding potential pitfalls."

Details of the new body's precise remit are still to be announced, and some have already expressed concern that 'over-policing' could hinder important research. Nevertheless, the fact that the issues involved are being discussed at a meaningful, industry-wide level is good news for all of us. And if you're not sure why, we humbly suggest you revisit *Terminator 2*...

BANKING

Cash, card or ring?



If you eyed the Visa payment rings worn by athletes at the Rio Olympics with envy, you'll be glad to hear that a similar device will be available to the public from December, with developer McLear Ltd accepting preorders now.

While the £40 McLear ring isn't the same device as the one used in Rio, Visa has said it does intend to market its own product soon. Both devices, like your contactless bank card, Oyster card or Apple Watch, use near-field communication (NFC) technology to let you make payments with a single swipe. The main advantages of the ring form factor are firstly that you don't need to have your phone on you, and secondly that it's a tad more discreet than brandishing your smartphone every time you make a purchase.





Rise Of The Tomb Raider is set to be one of the showcase games of Sony's new PS4 Pro console

GAMING

PS4 Pro coming in November

After months of speculation, Sony has announced details of PlayStation 4 Pro, the console formerly discussed as PlayStation Neo or PlayStation 4.5. The new console will go on sale in November, priced at £349.

The PlayStation 4 Pro will play all your existing PS4 games, but now boasts 4K resolution and support for virtual reality (VR) and high dynamic range (HDR) content, so PS4 Pro users will get the most benefit from PlayStation VR headsets, which launch in October. The new Pro is more powerful than its predecessor, with eight 2.1GHz (rather than 1.6GHz) cores in its CPU, and a GPU that's over twice as fast; this means new games will look better on the PS4 Pro than the PS4, though they'll play on both. It also has a new three-tier design, an extra USB port and a 1TB hard drive. Existing peripherals will still work, and PS4 and PS4 Pro gamers will be able to compete online.

If you're not interested in VR, however, Sony has also announced the PlayStation Slim, a more traditional mid-generation upgrade – that is, the same thing in a smaller box – that went on sale back in September, at a price of £249.

PHOTOS: GETTY, VISA, MERCEDES-BENZ X2

WANTED!

VOODOO MAGIC

ACER PREDATOR 21 X

Here's a gaming laptop that goes all the way to 11… or rather 21. Not only does the Predator 21X pack in *two* NVIDIA GeForce GTX 1080 graphics cards and a seventh-generation Intel Core CPU, it displays the output of all that processing grunt on a curved 21-inch screen. Of course, you probably don't *need* all that power, and its size and weight mean it's stretching the definition of the world 'portable'. But you want one anyway, don't you?

£TBC, acer.com





NOISE ANNOYS

SONY MDR-1000X

Unveiled at the recent IFA show in Berlin, these new Sony headphones are said to offer one of the most advanced noise-cancellation systems currently available. The wireless cans use improved ambient noise detectors and offer several new features, including a Quick Attention mode – cup your hand over one of the earcups to instantly turn the music off and the real world back on – and an Ambient Sound mode, which merely attenuates, rather than blocking, sound coming in from outside. We like.

£330, sony.com

UNDERCOVER COMPUTER

HP PAVILION WAVE

This may look like a desktop speaker, and in fact a 360° desktop speaker is exactly what it is – one that's been designed in conjunction with Bang & Olufsen. But *inside* that speaker, there also just happens to lurk a fully-specced PC. The Windows 10 machine has a sixth-generation Intel Core processor, up to 16GB of RAM and ports aplenty (3x USB 3.0, 1x USB-C, DisplayPort and HDMI), and can be specced to include an AMD R9 470M graphics ca[illegible].

$550 (£415 approx), hp.com





Speedy snaps

MEMORY MAKER

LOMOGRAPHY LOMO'INSTANT AUTOMAT

Lomography has long been at the forefront of the revival of interest in Polaroid-style instant photography. This is the Vienna-based outfit's latest baby, which has already exceeded its Kickstarter funding target six times over.

Available in four colours, the Lomo'Instant Automat offers automatic correction of shutter speed, aperture and flash output, and sports a lens cap that doubles as a remote control.

$175 (£130 approx), lomography.com



SMARTER THAN IT LOOKS

SKAGEN HAGEN CONNECTED

One by one, traditional watch companies have been getting on the smartwatch bandwagon, and this is Skagen's first foray into the sector. Available with a choice of face colours and strap styles, its deceptively analogue design boasts a sub-dial to help you monitor fitness goals. The watch will alert you to texts and emails by vibrating, and the buttons on the side can be programmed to play/pause music or take a photo.

$195 (£145 approx), skagen.com

AN E-BOOK AT BATHTIME

KOBO AURA ONE

While Amazon's Kindle dominates the ebook market, Kobo's e-readers have one major advantage – they're waterproof, which is a serious boon for those of us who like to read in the bath. The Aura One is the company's new flagship model, and with a backlit, 7.8-inch touchscreen, 8GB of memory and support for 14 popular ebook file formats, it's got the feature set to match the premium price tag.

$230 (£175 approx), kobobooks.com



APP FEED

Waze Carpool

Google's popular *Waze* traffic app will soon get an upgrade that adds a lift-sharing facility. The new system is currently on trial in San Francisco and Israel.

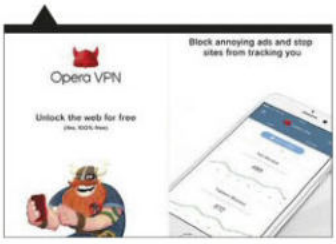
Free, iOS/Android



Opera VPN

Good news for the privacy-conscious: Opera's free virtual private network, which launched on iOS earlier this year, is now available to Android users, too.

Free, iOS/Android



Facebook Lifestage

Facebook targets Snapchatters and Vine creators with a video-led social network that's exclusively for under-21s. It's currently on test in the USA.

Free, iOS/Android



REPLY

Your opinions on science, technology and *BBC Focus*

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MESSAGE OF THE MONTH

Sticky situation

Regarding Will Hatton's remarks on children's sticky hands (October, p30), as a young lad I used to watch my dad with distaste as he turned the pages of a magazine by wetting his fingers to get a grip on the glossy paper. I could never understand why he had to do this as I never had any such difficulty. Later, as a father myself, I have to do the same thing! The explanation seems to be that as skin ages it loses its slightly moist surface, which has good 'grab' properties, and grows harder, drier and less 'grabby'.

My son used to have a bottle-opener that played a tune when you used it. At least it did when he held it, but it only worked for me if I moistened my hand first – the electronics in the detector needed some conductive moisture to activate the tune.

I don't think children's hands are actually sticky, it's just that their soft, young skin feels more moist and 'grabbier'!

Alan Kauffman, via email



WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Litelok bicycle lock, worth £85**. The British-made lock weighs just 1.1kg, yet is strong, flexible and easy to use. It's gained the gold standard from Sold Secure, so your precious bike should stay safe. **litelok.com**



Biscuit bother

I just finished reading the article 'Are my jeans to blame if my jeans don't fit?' (July, p80). It's great to see that you are trying to explain why people are getting fatter.

What I'd like to read about next is the solutions to problems such as obesity and high biscuit tolerance, etc. Are there any?

Joanna Kukuczka, via email

There's not a shadow of a doubt in my mind that I'm a unfortunate victim of 'high biscuit tolerance'. We'll look into it! ***– Ed***

Conspiracy, what conspiracy?

Regarding the news piece about conspiracy theorists in this month's issue (October, p19), it is quite clear to me that the research team at Carnegie Institution is in thrall to our Illuminati overlords. You cannot trust their findings, because… errr… reasons!

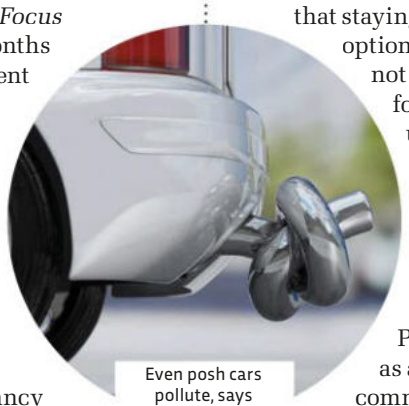
Will Hatton, via email

No smoke without fire

I signed up to *BBC Focus* magazine a few months ago. I find the content to be spot on.

On reading the main letter in the October issue (p30), I had to get in touch. The writer is so self-obsessed and consumed by the status he thinks he has by owning a 'fancy car' that he can do no wrong. If only he could see past his need to have more/better stuff than the next person, he would see that his argument about which combustible fuel is worse and which vehicle is worse is irrelevant. They are all planet killers, no matter how shiny they are, or how big they make your status appear. Come on, electric, it's your time to shine!

Craig Smith, via email



Even posh cars pollute, says Craig Smith



Editor Dan's breakfast

Starman

With regard to your article concerning a possible manned expedition to the planet Proxima b (October, p32), there is a rather nasty scientific concept called 'entropy', which means, among other things, that staying still is not an option. If a society does not keep on going forward, it will end up going backwards (there have been numerous examples in our history). Proxima b orbits the star Proxima Centauri; as a number of commentators have pointed out, it is a less powerful star than our Sun, but with a much longer estimated lifespan. It has been suggested that Proxima b could serve as a refuge for the

PHOTOS: GETTY X3, ESO

human race, when our Sun reaches the end of its lifespan.

A successful expedition to Proxima b would mark humankind's emergence as an interstellar civilisation. I have come across studies indicating that, even with slower than light drives and the failure of some of the expeditions, it would take a comparatively short time for humanity to spread throughout the Galaxy. We could place ourselves beyond the reach of almost any conceivable disaster.

Robert Heinlein, the late science-fiction writer, once suggested that, because of the actions of the Apollo astronauts, it was possible that the human race might outlive the planet on which he was standing. That future is now that much closer.

Peter Davey, Bournemouth

City living

Brendan Kelly may like cities (September, p72), but I wonder where he gets the evidence that others do? The fact that so many live in cities may be because that is where there is employment. I had to visit my London-based accountant recently, and the experience reminded me of all the reasons I left: the pollution; the unpleasant smells; the incessant noise; the apparent unconcern of anybody for anything but themselves, etc. I have never met anyone in Kent who says they wished they lived in London – most of them have moved out for the same reasons as me. I would also like to see evidence of any 'hard-wiring' that leads us to go to cities for more human contact. Societies with the highest level of human contact seem to be the most troubled; those where the citizens live far apart appear to be the most peaceful. Perhaps schizophrenia is caused by people pretending to like city life when, underneath, they really don't?

John Brightwell, via email

Cities can be infuriating in ways that rural settings rarely are. But still people flock to cities for all kinds of reasons, including employment, education, tourism and entertainment. We may never understand this fully, but we do know that cities are growing rapidly. Either millions of people are making a move that they will later regret, or cities have a magical allure that we have yet to comprehend. I opt for the latter. But I would, wouldn't I? After all, I live in a city.

– Prof Brendan Kelly



Peter Davey thinks that Proxima b could offer humans a home from home

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Special issue



THE AMAZING BRAIN

The organ between your ears is one of the most complex machines on the planet. This special edition from the *BBC Focus* team explores the science behind free will, intelligence, addiction, and more.

PHOTOS: GETTY X 2

MAKING WAVES

Your phone might be smart, but how good is it at reproducing music? The Hugo is a genius way to get studio-quality audio from any device and perfect your listening experience

Twenty years ago, if you'd told music fans they'd one day be able to carry their entire record collection in their pocket, you'd have been laughed out of the room. If you'd gone on to add that they'd also be able to access nearly every song ever recorded at the touch of a button, wherever they were, you'd have been met with concerned looks and some sage advice to maybe lay off the drink.

Yet that's exactly what's happened. The convergence in development of a few different technologies – smaller microprocessors, digital encoding and high-speed internet – has ushered in a golden age for music lovers. Music has never been easier to access. But portability and accessibility has come at a cost: quality.

LOW FIDELITY

You see, reproducing audio is a complicated business. Over the past few decades we've experimented with a few different methods, which you can read about on the opposite page. But these days, convenience means most of us get our musical fix from digital formats.

At a basic level, a digital audio file is a string of binary code, a lengthy series of ones and zeros that represents all the audio information that makes up a song. To reproduce the recording, a chip in your laptop or phone called a digital to analogue converter (DAC) reads the code and generates an electrical signal. When that signal reaches a loudspeaker, you hear sound.

Unfortunately, using a good quality DAC isn't a priority for most electronics manufacturers. Developing the code and circuitry needed is time-consuming and expensive, so typically smartphones and computers ship with a budget option. That means their audio output is stripped of a lot of information, resulting in an end product that sounds a long way from what the artist intended. But there is a solution.

The Hugo is an external DAC created by the audio engineers at Chord Electronics. It's a seriously high-end bit of a kit, engineered using techniques developed over 25 years of working with some of the world's leading broadcasters, recording studios and film stages. Chord's proprietary technology doesn't add or remove anything from the original recording; instead, it provides a window onto the original, letting you hear it exactly as the artist intended. The difference is astonishing.

The Hugo is designed to be versatile. It's highly portable and robust, and a single charge lasts 10 hours, so it's ideal for listening on the go, but also has the power to improve even the most high-end hi-fi. It's found its way into professional audio setups around the world, where its ability to accurately reproduce waveforms is vital in mixing and mastering. There's also a desktop version, the Hugo TT, for home use.

If you'd like to hear the difference a Hugo can make, you can enter the competition opposite. In the meantime, let Chord Electronics give you the lowdown on how audio reproduction has developed over the last few decades.



WHAT HI-FI? AWARDS 2014

DACs
Best DAC £1000+
Chord Hugo

Find out more about the Hugo's groundbreaking technology at **chordelectronics.co.uk/chord-hugo.asp**



VINYL

Unlike modern audio reproduction, vinyl records store sound in a mechanical way. That means there's a direct physical relationship between the audio and the record itself. During the pressing process, recorded soundwaves are physically carved into the record's plastic surface by a stylus. This emulates the peaks and troughs of any given soundwave; when a different kind of stylus runs down the grooves it vibrates in the exact same way. The stylus is connected to an electromagnetic device called a cartridge, which converts the vibrations to electrical signal, then to an amp, which increases their energy. A loudspeaker converts this electrical signal to soundwaves.



CD

CDs are made from a thin layer of aluminium sandwiched in polycarbonate, with a protective layer of lacquer. Unlike tape and vinyl, music is stored digitally on a CD, as a string of numbers. That's done through a process called sampling, in which audio is 'listened to' 44,100 times a second by a piece of software which converts each sample to binary code. The result is written to the aluminium layer using a laser, where a burn represents a zero, and an unburnt area represents a one. When a laser reads these marks it understands whether it's looking at a one or a zero by the way the light reflects – a zero will reflect smoothly, while a one will cause it to scatter. A DAC converts the binary readings to an electrical signal, which is converted to sound by a loudspeaker.



WAV

WAV encoding was developed in 1991, so it predates the widespread adoption of MP3s by about 10 years. But they're actually a far more accurate reproduction. To understand why, you need to know how MP3s work. Both formats convert audio to binary using the same 44.1khz sampling as CDs, but MP3s are designed to be as small as possible. They do that by using the principles of psychoacoustics – the study of how we perceive sound – to remove information the human ear isn't consciously aware of. For example, there are certain frequencies humans can't hear, so they're removed. Equally, if we hear a loud sound and a quiet sound together our brain ignores the quiet sound – so the MP3 encoder takes it out. There are some advantages to this: MP3s take up much less memory, and they provide a reasonably accurate reproduction. But all that extra information means that WAVs, like vinyl and CDs, have an indefinable richness to their sound that MP3s can't provide.

CHORD

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Is technology changing our brains?

We increasingly rely on social media to talk to friends, GPS to navigate and the web for information. But is that wise?

Words: **Jo Carlowe**

Google is making you stupid, your iPhone's making you fickle and your social networks are making you anti-social. If the newspaper headlines are to be believed, our brains are under attack. Modern technology is pummeling each of us into a cognitive wreck, and if we aren't careful we'll be beaten into a stupor.

Of course, the real story isn't as clear-cut as all that. But stories persist because the sense that something is eroding our mental abilities *feels* right. We struggle to remember our own phone number, when only a few years ago we could recall dozens. Online, readers prefer short, simple stories to long, nuanced pieces (although we're sure *BBC Focus* readers are the exception), and we all know someone who breaks out in a sweat when separated from their smartphone.

So what's really happening? The first thing to consider is that this kind of 'neuro-anxiety' about the tools we use is nothing new. In 370 BC, Plato warned that the Greeks' "trust in writing" would "discourage the use of their own memory". Sound familiar?

The reality is that our brains *do* change when we use a smartphone or computer – but they also change when we use a pen, a screwdriver, or any other tool for that matter. They change when we mow the lawn, play golf or cook dinner. Our experiences continually shape the way the brain works. So the question isn't really 'is tech rewiring our brains?' but 'how are our brains adapting to living in today's screen-first, always-online, networked world?'

Scientifically speaking, we're a long way from definitive answers, but we looked at the latest research and talked to leading experts in their fields to discover how they think our collective brains are being affected…

ILLUSTRATION: ANDY POTTS

Attention

Phones buzzing with text messages, Facebook notifications and news alerts continually tempt the world to distraction. Many experts believe that this incessant bombardment, and the need for instant answers, has eroded our ability to focus.

A 2015 study by Microsoft surveyed 2,000 Canadians and used electroencephalograms (EEGs) to watch the brain activity of a further 112 people. Their analysis found that the average human attention span had dropped from 12 seconds in the year 2000 to just eight seconds. Goldfish are thought to posses a impressive nine-second attention span.

This wasn't just a company chasing a catchy headline. The research in the area is mostly anecdotal, but a number of surveys do back up the idea that attention spans are shrinking. In a 2012 Pew Research Center survey of more than 2,000 teachers in the US and Puerto Rico, 87 per cent reported that their students had short attention spans and were easily distracted. The same year, a UK poll from the learning company Pearson reached the same conclusion. Of 400 UK English teachers questioned, and 2,000 parents of preschool and primary-aged children, seven out of ten said that children's attention spans were shorter than they used to be.

Meanwhile in the US, the Centers for Disease Control and Prevention has reported that 11 per cent of school-age children have, at some point, been diagnosed with Attention Deficit Hyperactivity Disorder. Before 1990, the figure was less than 5 per cent.

These studies shine a spotlight on our diminishing attention spans, with modern technology in the crosshairs as the culprit. More research is needed if we're to be sure of a causal relationship, but experts feel certain they'll find one. "I am personally convinced that technology has led to a decreased ability to focus and wait, and an increased need for immediate information," says neuroscientist Prof Russell Poldrack, of Stanford University.

Verdict: Yes, the information age has shortened our attention span.





Is internet addiction real, and should we be worried?

In a famous test, rats given a lever to activate their nucleus accumbens (the brain's pleasure centre, responsible for dopamine production) pressed it continuously until they died of starvation or exhaustion. The same brain structure lights up when addicts score a fix.

Reports have emerged of young men dying following excessive bouts of video game playing: like the rats, they forgot to eat, sleep or move. In one well-known case, a South Korean man died after 50 hours of non-stop gaming.

Studies suggest that brain activity seen in excessive internet users resembles that of drug addicts, with less grey matter volume in parts of the prefrontal cortex linked to willpower. But cause and effect is not clear: the difference could be a precondition for, rather than a result of, excessive internet use.



Mood

Scientists have been reporting strong links between heavy internet use and depression, with a particular focus on social media. This came as no surprise to health education expert Dr Aric Sigman, who says high exposure to social media can leave people feeling inadequate. "There is a relationship between the amount of time you spend on social media and increased body dissatisfaction. High consumption of idealised images seems to activate neural networks in the brain like the amygdala, associated with fear and anxiety."

Sigman cites a study in which girls who instant messaged their mothers released the stress hormone cortisol, rather than the feel-good hormone oxytocin associated with face-to-face interaction. "We may be hard-wired to need a certain amount of contact with people we care about. A deficit in human contact may result in health problems."

Facebook, it seems, might not be giving us enough facetime.

Verdict: Technology can affect mood, but it depends how we use it.

Memory

With phone numbers, routes and facts just a touch away, we're becoming less reliant on our memory – and German neuroscientist Manfred Spitzer warns this 'cognitive offloading' could be leading to a kind of 'digital dementia'.

Studies on internet and gaming addicts has uncovered atrophy (shrinking) in the brain's grey matter, says the University of Bedfordshire's Prof James Barnes. Overdosing on tech seems to cause the frontal lobe – a brain area that governs functions such as planning and organising – to suffer in particular. However, he adds that more research is needed on 'real' as opposed to 'addicted' internet users.

Digital offloading may also make memories less vivid. A US study asked museum visitors to photograph some exhibits and just look at others. The next day their memory was tested. Visitors were worse at recognising objects they had photographed, and worse at recalling details about the objects they'd photographed.

But Dr Sam Gilbert, of University College London, says there are also positives. "Research shows that when you save information to an external store like a computer, this can help you to store new memories. Your mind is no longer cluttered with information that you don't need."

Verdict: Short-term changes are likely but more research is needed on long-term impact.



PHOTOS: GETTY X2, ALAMY

Social skills



"Throughout the world – in caves, huts and houses – it was almost a reflex to turn your face to a returning parent," explains health education expert Dr Aric Sigman. But, he says, kids are now so glued to their screens they no longer look up.

Though some parents might be glad of the respite that screen-time provides, research suggests that excessive screen use seems to damage our ability to interpret faces. "They [excessive internet users] find it more difficult to read faces in experiments," explains Sigman.

In one study, children showed a significant improvement in reading facial emotions after spending five days away from all devices. In another experiment, Chinese psychologists scanned the brains of 'normal' versus 'excessive' internet users, while they viewed images of faces and objects. The internet junkies showed smaller brain wave responses to faces than their peers.

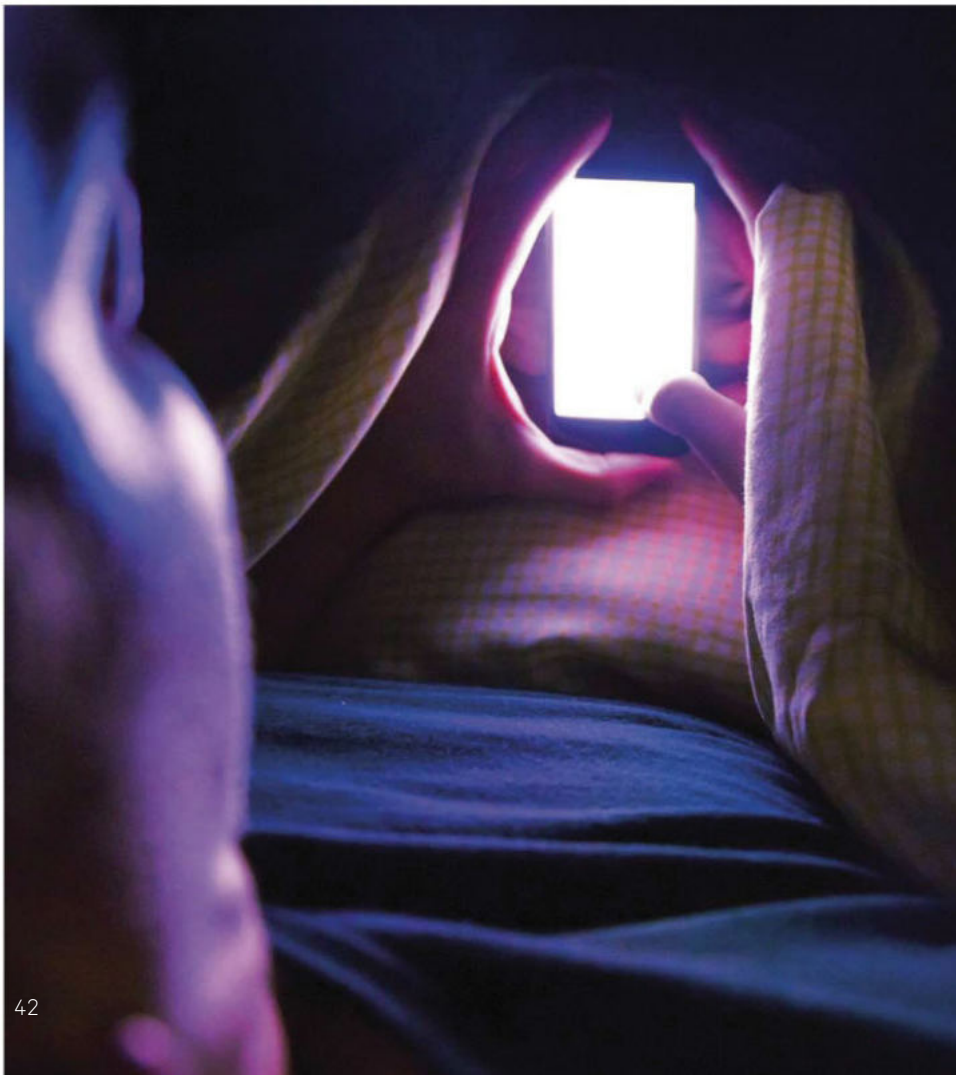
Sigman's view is that technology use itself isn't damaging – just like sweets, it's simply a case of ensuring children don't consume too much, too often. Prof Mizuko Ito of the University of California, meanwhile, believes that a reasonable serving of new media can actually be beneficial for the development of youngsters' brains.

"Young people who are taking advantage of online tools like search, forums, open educational resources and complex games are learning at a more accelerated rate, and in specialties that they would never have had access to in earlier eras," she argues.

However, she adds that for disengaged kids in distressed circumstances, digital media can be a distraction from positive learning and social engagement.

"It's not the availability of media that determines this, but whether they have life opportunities, positive peer influences and caring adults who support and guide them to positive media engagements."

Verdict: New media is just a place to 'hang out', but for the socially disengaged there are risks.



Sleep

We now spend more time on our devices than we do sleeping. According to an August 2015 Ofcom survey, we engage in media or communication activities such as texting or gaming, for 8 hours and 41 minutes daily, and sleep for 8 hours and 21 minutes.

Technology keeps us up for two reasons. First, we are stimulated by the content. Second, the LED screen emits blue light, which prevents the brain from producing the sleep hormone melatonin. The blue light is in a bandwidth one sees in everyday sunlight, explains health education expert Dr Aric Sigman. "The blue light from your phone or tablet informs your pineal gland that it's morning and it should shut down production of melatonin."

In the journal *Preventive Medicine* (2016) researchers found a strong association between social media use and sleep disturbance, and warned of a link between sleep deprivation and depression. Sleep deprivation has also been associated with obesity and poor academic performance.

Verdict: Screen use at bedtime will change your sleeping patterns.

Reading

When we read, we construct a mental representation of the text in our minds, much as we do when we look at terrain and create a mental map in our heads. But experts warn that we read text on screens differently, preferring to skim, scan and click hyperlinks, rather than 'deep reading' in the old-fashioned sense.

Norwegian experts tested the theory by dividing students of comparable reading skills into a paper group and LCD monitor group. In a follow-up reading comprehension test, the group who'd read texts on computers performed a little worse than the traditional readers. And a Swedish study in which volunteers completed a reading test reported similar findings: those who took the test on a computer scored lower, and reported higher stress levels, than those who took the same test on paper.

Prof Ziming Liu, of the School of Information at San José State University in California, believes digital screen readers engage in greater use of shortcuts such as browsing for keywords. His research also reveals that screen users are more likely to read a document only once and expend less time on in-depth reading.

Verdict: More research needed, but technology may make us less thorough.





PHOTOS: GETTY X4

Multitasking

Our 'always-on' culture has been dubbed "infomania" by psychologist Dr Glenn Wilson, who tested the IQs of subjects in either a quiet room or one with mobiles ringing and emails arriving. The technological distractions diminished IQ by 10 points.

Similarly, a US study found that students who instant messaged with friends during a reading task took between 22 and 59 per cent longer to complete the task, even accounting for the additional time spent messaging.

Brain-imaging reveals that multitasking uses different brain regions to focusing on one task. Learning while focusing on one task uses the hippocampus, which stores ideas and creates rich and flexible memories. This area allows us to compare old ideas with incoming data to put what we learn into context, effectively leading to deeper understanding. Multitasking, on the other hand, uses the striatum — a brain region that stores procedures and skills. New information acquired using the striatum is less flexible and can't be generalised in the same way. This suggests that knowledge acquired while multitasking is less deeply embedded in our memories.

Researchers from University College London recently linked frequent multitasking to smaller grey matter density in the anterior cingulate cortex (ACC), which is the brain region that is involved in empathy and decision-making. However, it is unclear whether having a smaller ACC makes you more likely to multitask, or whether it's multitasking that causes the ACC to shrink.

But some experts say technology has made us all more skilful at multitasking. Hong Kong researchers report multitaskers are better at multisensory integration, while a 2016 study from Microsoft found our ability to multitask has "improved drastically" since the turn of the millennium.

Verdict: Technology may make us more adept multitaskers, but perhaps at a cost.



Navigation

In 2000, a study found that taxi drivers who acquire The Knowledge – which requires memorising thousands of London streets – have a greater volume of grey matter in the posterior hippocampus but less in the anterior hippocampus, making them better at memory tasks involving landmarks but poorer at recalling complex visual information. This provided evidence for plasticity in the adult human brain.

Could our reliance on GPS also be changing the way our brains work? Researchers from McGill University in Canada used fMRI scans to compare GPS users with non-GPS users. Those who navigated without GPS had higher activity and a greater volume of grey matter in the hippocampus than those who relied on GPS.

In another study, people who drove a route using sat-nav could not remember scenes from the journey as well as those without sat-nav, and were poorer at retracing their steps from memory alone.

"It's possible that reliance on technology could cause some brain areas to grow and others to shrink," says University College London's Dr Sam Gilbert. "Something similar was shown in the original taxi driver study. But occasional use of sat-nav probably won't have as strong an effect as learning The Knowledge and relying on it as part of your job."

Verdict: Yes, technology may change our brains when it comes to navigation

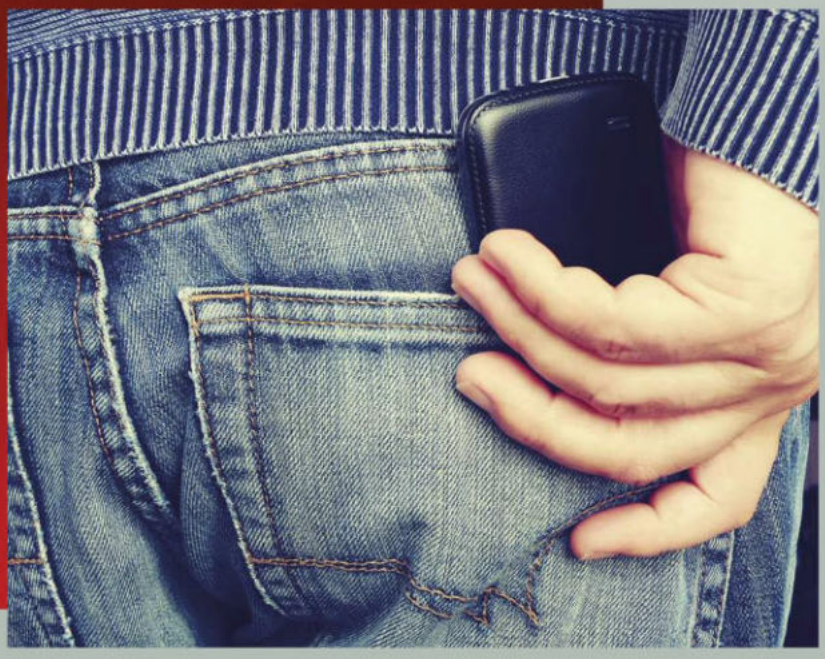


Jo Carlowe is a freelance journalist with a degree in psychology. Her work regularly appears in UK broadsheet newspapers as well as in medical and scientific publications.

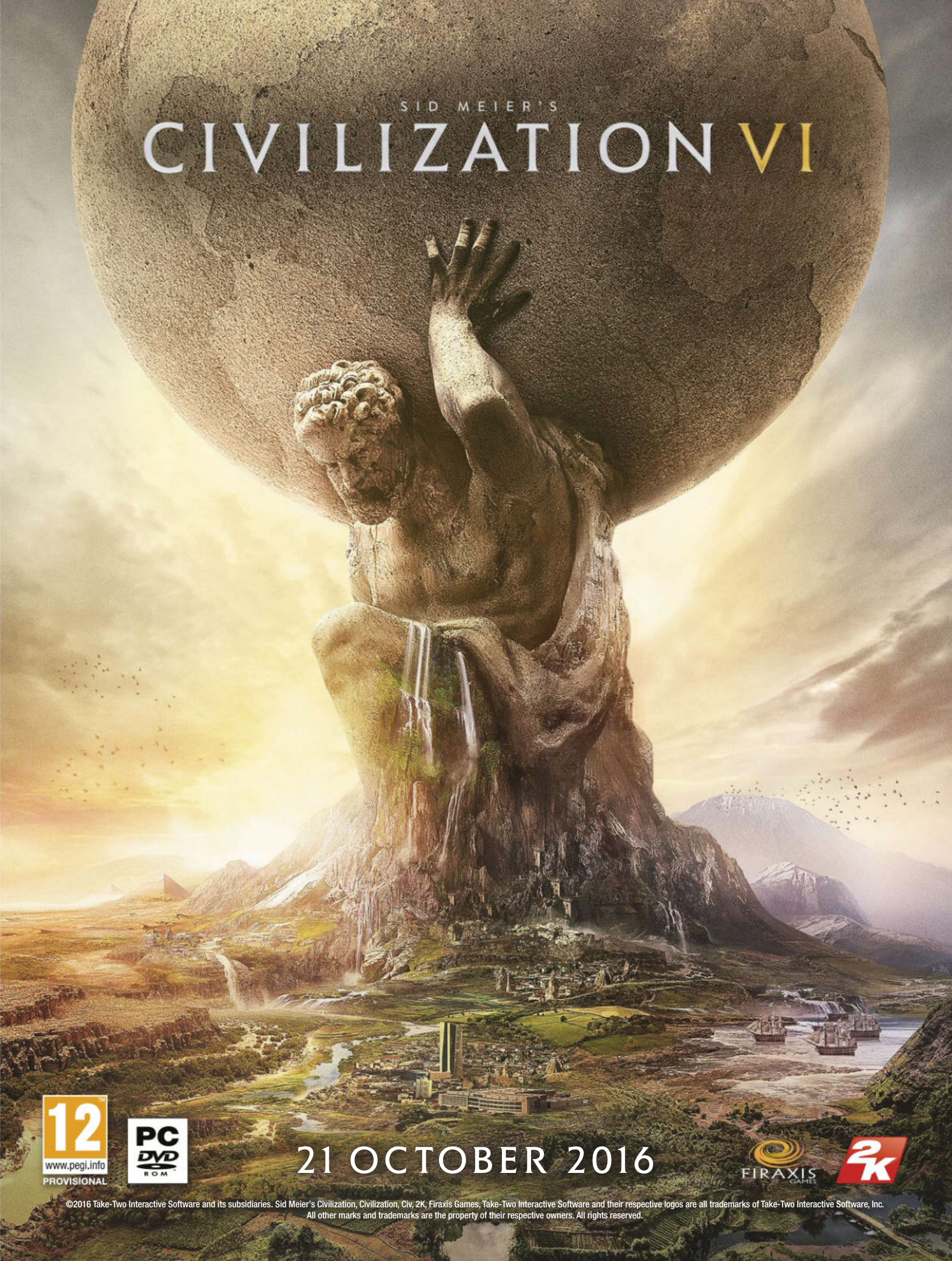
Ghost phonecalls

Have you ever imagined your phone is vibrating in your pocket, only to pull it out and find you imagined it? You're not alone: it turns out 'phantom vibration syndrome' is a common phenomenon. A study of doctors at a hospital in Massachusetts found that 70 per cent of doctors reported experiencing such 'ghost calls', while a US study of college students found up to 90 per cent were familiar with the phenomenon.

But fear not – psychologists say this is not a sign of madness, but rather that we are so alert for phone calls and messages that we misinterpret slight muscle spasms as proof of a call. We are so anxious not to miss a call that our brains overcompensate by biasing us towards false alarms.



PHOTOS: GETTY X2



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ARE WE ON THE BRINK OF BEATING CANCER?

The numbers show survival rates of many forms of cancer have climbed dramatically over the last 50 years, but how close are we to finding a cure?

WORDS: SIMON CROMPTON

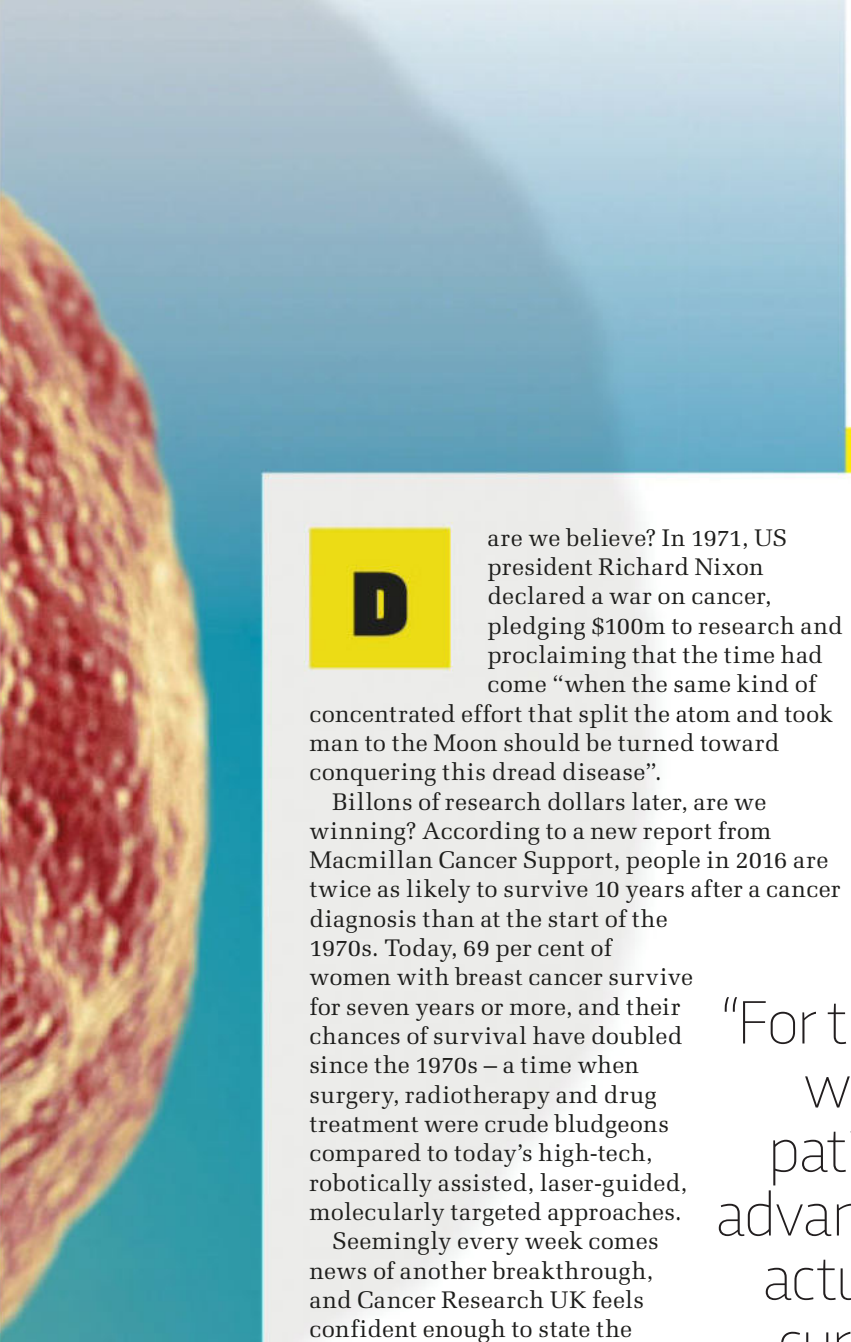


PHOTO: ALAMY

Dare we believe? In 1971, US president Richard Nixon declared a war on cancer, pledging $100m to research and proclaiming that the time had come "when the same kind of concentrated effort that split the atom and took man to the Moon should be turned toward conquering this dread disease".

Billons of research dollars later, are we winning? According to a new report from Macmillan Cancer Support, people in 2016 are twice as likely to survive 10 years after a cancer diagnosis than at the start of the 1970s. Today, 69 per cent of women with breast cancer survive for seven years or more, and their chances of survival have doubled since the 1970s – a time when surgery, radiotherapy and drug treatment were crude bludgeons compared to today's high-tech, robotically assisted, laser-guided, molecularly targeted approaches.

Seemingly every week comes news of another breakthrough, and Cancer Research UK feels confident enough to state the ambition that by 2034, three in four people will survive cancer. So in less than 20 years, will cancer no longer be the dreaded disease it is today? Is it finally being beaten? Many cancer specialists will say as much – but what they mean by 'beaten' varies somewhat.

Some types of cancer are already curable. Nearly all men who get testicular cancer can be cured; UK mortality rates have decreased by 82 per cent since the early 1970s. New biological drugs have transformed the life expectancy for most people with newly diagnosed chronic myeloid leukaemia (a blood cancer) from two or three years to normal. But other cancers are just as lethal as they were 50 years ago. Survival rates for pancreatic cancer – the 10th most common cancer, which kills 9,000 people in the UK annually – are just 1 per cent after 10 years.

"For the first time we've had patients with advanced disease actually being cured. That's extraordinary"

The task of beating cancer seems all the more daunting in the knowledge that it is not just one disease but over 200, and every case has the genetic individuality of a snowflake. The last two decades have seen enormous advances in targeted drugs, which home in on the particular genes and proteins found in specific cancers, but the chances of finding one that will hit all of them – a magic bullet – is still remote.

And what does 'winning the battle' mean, anyway? Doctors consider a patient's cancer to be 'cured' when they have been disease-free for five years – but if the aim is for everyone who gets cancer to be 100 per cent disease-free for the rest of their lives, the war is just beginning.

Experts like Prof Clare Isacke, a breast cancer researcher who is academic dean at the Institute of Cancer Research, believe that total cure should be the aim. But keeping everyone who gets cancer alive, and holding the disease in check with a variety of treatments, is also a laudable and realistic goal.

Isacke is excited about recent developments in immunotherapy, techniques that boost the body's own defence systems and cause it to attack the cancer. Studies on skin cancer are showing what might be possible: Isacke cites data showing that patients with widespread melanoma are still alive five years after being treated with new immunotherapy drugs such as nivolumab and ipilimumab.

"Everyone wants to rush out new versions of these kinds of drugs, because although they're not going to cure all cancers, for the first time we've had patients with advanced disease actually being cured. That's extraordinary," she says. "Improvements are going to come from multiple approaches – from prevention, advances in surgery and radiotherapy, all the way through to new drug treatments."

Over the following pages, we take a look at some of the techniques we could harness to finally beat cancer for good. ●



PHOTO: ALAMY, GETTY

PREVENTING CANCER

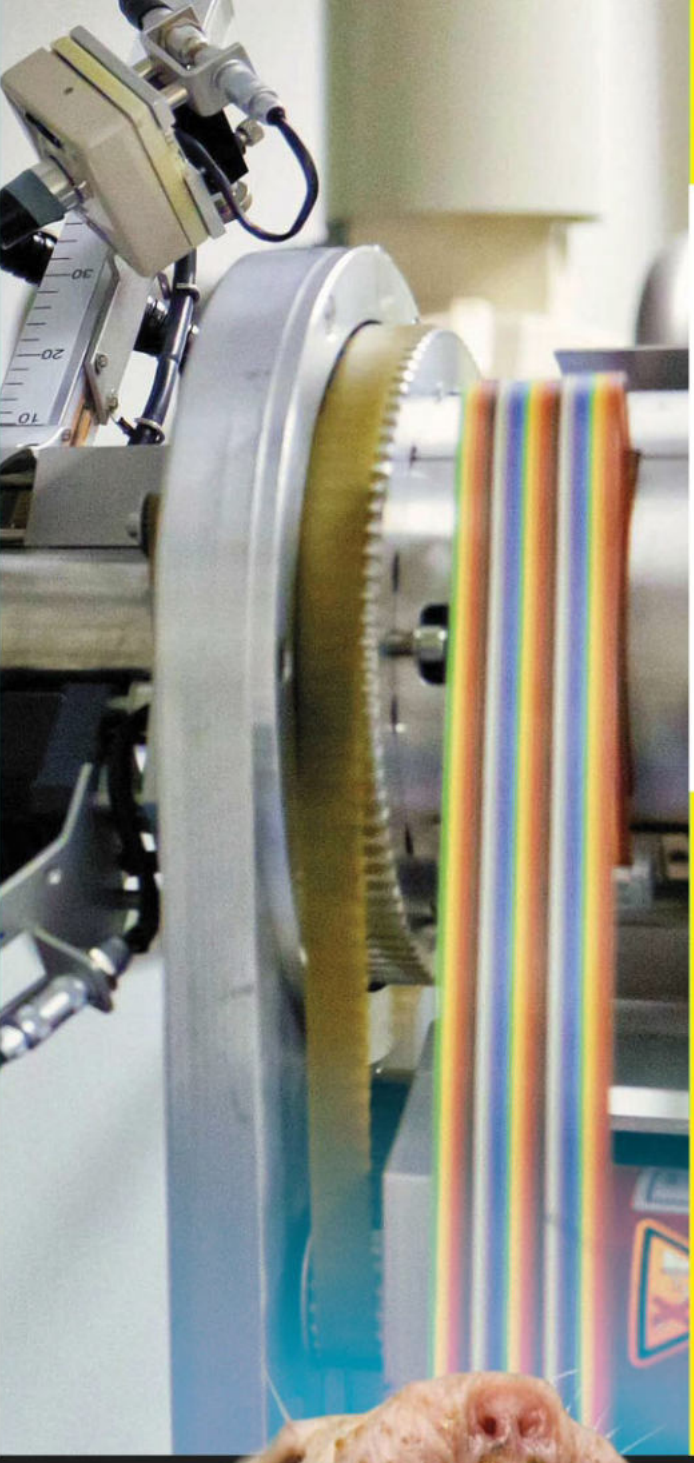
BE GOOD TO YOURSELF
Preventing cancer may still offer the best prospect of conquering it. According to the International Agency for Research on Cancer, at least half of the world's cancers are preventable and it is possible that up to 90 per cent probably have an environmental or lifestyle trigger. One study suggested that if people simply acted on advice about smoking, diet, alcohol and other well-known risk factors, more than 40 per cent of UK cancers would be prevented.

Researchers continue to find triggers. A World Health Organization review recently established that drinking very hot tea or coffee does seem to be linked with throat cancer. This follows another global review which came to conclusion that processed meat is carcinogenic.

BEFRIEND A MOLE RAT
Naked mole rats, which never die of cancer, are proving a valuable ally to scientists searching for ways of preventing the disease. The hairless rodents secrete a sugary goo made of hyaluronic acid, which makes their skin soft and wrinkly and also forms a protective cage around cells, preventing tumour cells from replicating. Scientists in London, Haifa and Texas are all now investigating whether genetic engineering might endow other mammals with a similar trait.

CATCHING CANCER EARLY

A blood test could detect cancer 10 years before symptoms appear



LEFT: A patient with eye cancer undergoes treatment that uses an ion beam



Naked mole rats might not be the prettiest of animals, but that wrinkly skin could hold the secret to beating cancer

Cancer is often curable if it's caught early enough: the real challenge comes when it has spread, and become complicated and resistant to drugs. This is why screening programmes (such as the ones that exist in the UK for breast, cervical and bowel cancer) to find the disease at its earliest stages play an important part in beating cancer.

But could screening for cancer soon be as simple as having a routine blood test? Doctors are already able to pick up specific 'markers' in the blood of cancer patients to see if a particular cancer is coming back – but they have to know what they're looking for. Scientists at Swansea University believe they have come up with a finger-prick blood test that might spot cancer in any person, up to 10 years before symptoms appear. By studying patients with cancer of the oesophagus (throat), they discovered mutations that occur in red blood cells long before any other sign of the disease appears, and are now studying whether the same applies for pancreatic patients as well. According to lead researcher Prof Gareth Jenkins, the test could have enormous potential since early diagnosis is a key factor in cancer survival rates.

SCALPELS AND PROTON BEAMS

Surgery and radiotherapy cure more cancers than all the drugs combined. Surgery cures because the cancer can be cut out of the body straight after diagnosis before it has had chance to spread.

According to Cancer Research UK, radiotherapy cures more patients than all new drugs put together. It exposes cancer cells to radiation, breaking their DNA and stopping them dividing.

The problem with radiotherapy has always been the possibility of serious side effects, including impotence, heart problems, bowel incontinence and even a second cancer. But new techniques such as proton beam therapy and stereotactic ablative radiotherapy use such sophisticated targeting techniques that the benefits of the radiation far exceed the risks. ●

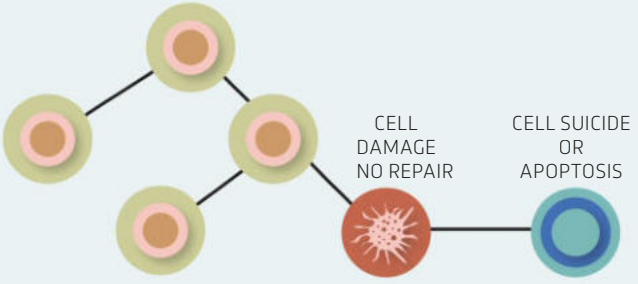
HOW DOES CANCER ARISE?

DNA inside every cell contains genes that provide coded messages about how the cell should behave. Normally, genes make sure that cells reproduce in an orderly way, only dividing into two when that's what's needed to keep the body healthy. Sometimes, though, genes get copied or damaged when a cell divides. This is called a mutation.

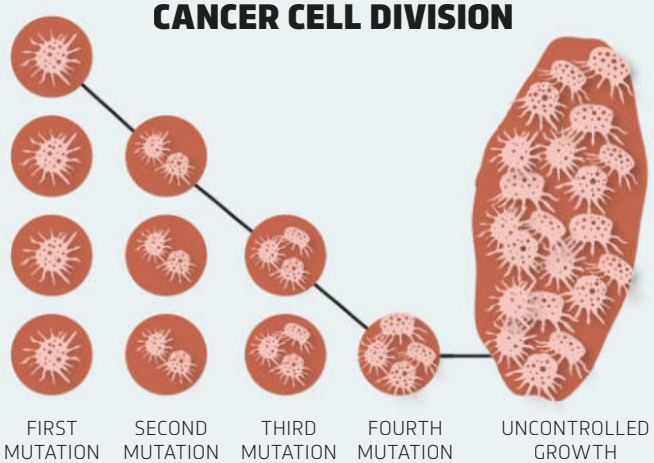
Normally, these damaged cells will self-destruct, but sometimes the damage prevents self-destruction. If this happens several times and mutations build up, it can mean that the cell no longer understands instructions regulating division. So cells divide out of control, forming lumps or tumours. Each time faulty cells reproduce, the more likely they are to produce new mutations, making them more different from healthy cells. Small groups of cancerous cells can break off the main tumour and be carried away to other parts of the body in the circulatory system. They form new tumours where they land, called metastases.

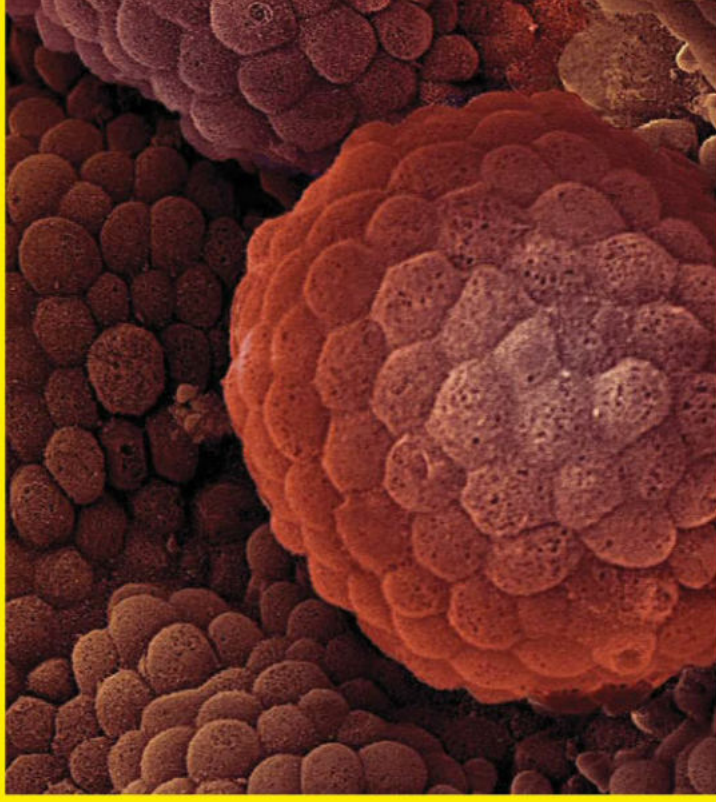
But why do cancer-causing gene mutations occur in the first place? Well, some people inherit faults in particular genes that make mutations more likely to happen. Exposure to environmental factors like chemicals and tobacco smoke can also cause mutations. Most researchers believe that sheer bad luck also plays a part, since mutations are randomly caused by processes within cells.

NORMAL CELL DIVISION



CANCER CELL DIVISION





CURING CANCER WITH DRUGS

Could we press the 'pause' button on cancer?

The problem with most current cancer drugs is that they only work for so long. If cancer is not caught early on, cells will continue to mutate rapidly, becoming more diverse and therefore trickier to target. But a remarkable discovery is providing a new understanding of this process.

Until recently, scientists believed that all cancers mutated in a linear fashion, with cells constantly changing but all of them genetically identical at any given point. However, new DNA sequencing techniques allowed researchers to accurately read the genetic mutations in a tumour. This led to a groundbreaking study that finally busted the linear myth in 2012.

Researchers funded by Cancer Research UK and led by Prof Charles Swanton demonstrated that cancers evolve according to Darwinian principles, forming branch after branch off a main tree and

PHOTOS: GETTY X2, SCIENCE PHOTO LIBRARY





ABOVE LEFT: Prostate cancer, as seen in this image taken by a scanning electron microscope, tends to occur in older men and has an excellent cure rate

ABOVE RIGHT: Chemotherapy doesn't work on rapidly evolving cancers

giving rise to remarkable diversity within one tumour. Different samples taken from just one kidney patient in the study revealed 118 different mutations. Yet a conventional biopsy might reveal just 25.

Since many modern drugs only target one mutation, the discovery makes the task of treating cancer sound even more daunting. Yet it provides a basis for new treatments that combine drugs. And understanding that cancers grow according to natural selection principles also provides researchers and drug developers with a focus: targeting the common mutations on the trunk of the evolutionary tree rather than the rarer ones on the branches which have sprung from the commoner mutations.

"I think everyone now accepts that this diversity is the norm rather than the exception," says Swanton. "Everywhere I go now, people are talking about heterogeneity as the reason for drug failure, whereas in 2012 nobody was. As doctors, I think we need to think about how we can manage evolution in a very clever way, and most importantly learn from environmental ecology and say how can we set about structuring clinical trials differently to take account of it."

KEEP IT ALIVE

Because cancers evolve so quickly, they can very rapidly become resistant to drug treatments, including chemotherapy. Drug-resistant cancer cells will survive and take over the tumour once the drug-sensitive cells have been killed off, so scientists are now exploring whether the best chemotherapy strategy is actually to keep drug-sensitive cells controlled but alive, so that they continue to out-compete the resistant cells. Researchers in Florida, for instance, have demonstrated that mice live longer if given lower doses of chemotherapy, controlling the cancer environment so that the law of survival of the fittest works for patients, not against them.

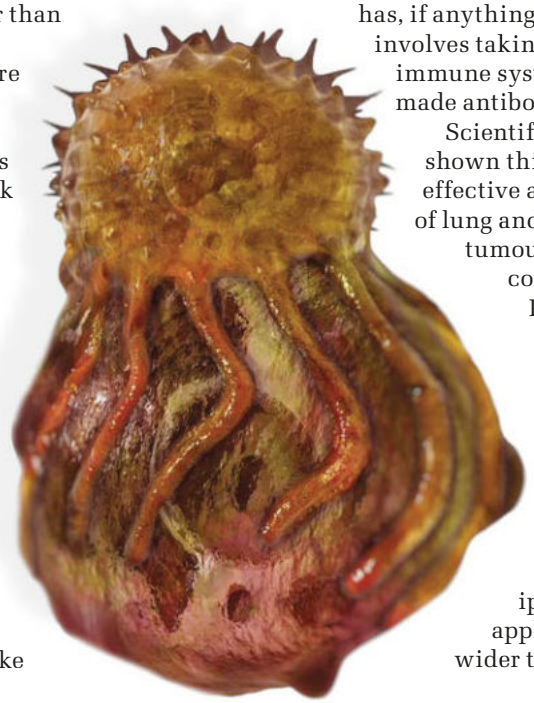
BOOST THE IMMUNE SYSTEM

Immunotherapy – stimulating the body's defence mechanisms to recognise and fight cancer – was hailed by the scientific journal *Science* as 2013's most groundbreaking scientific advancement.

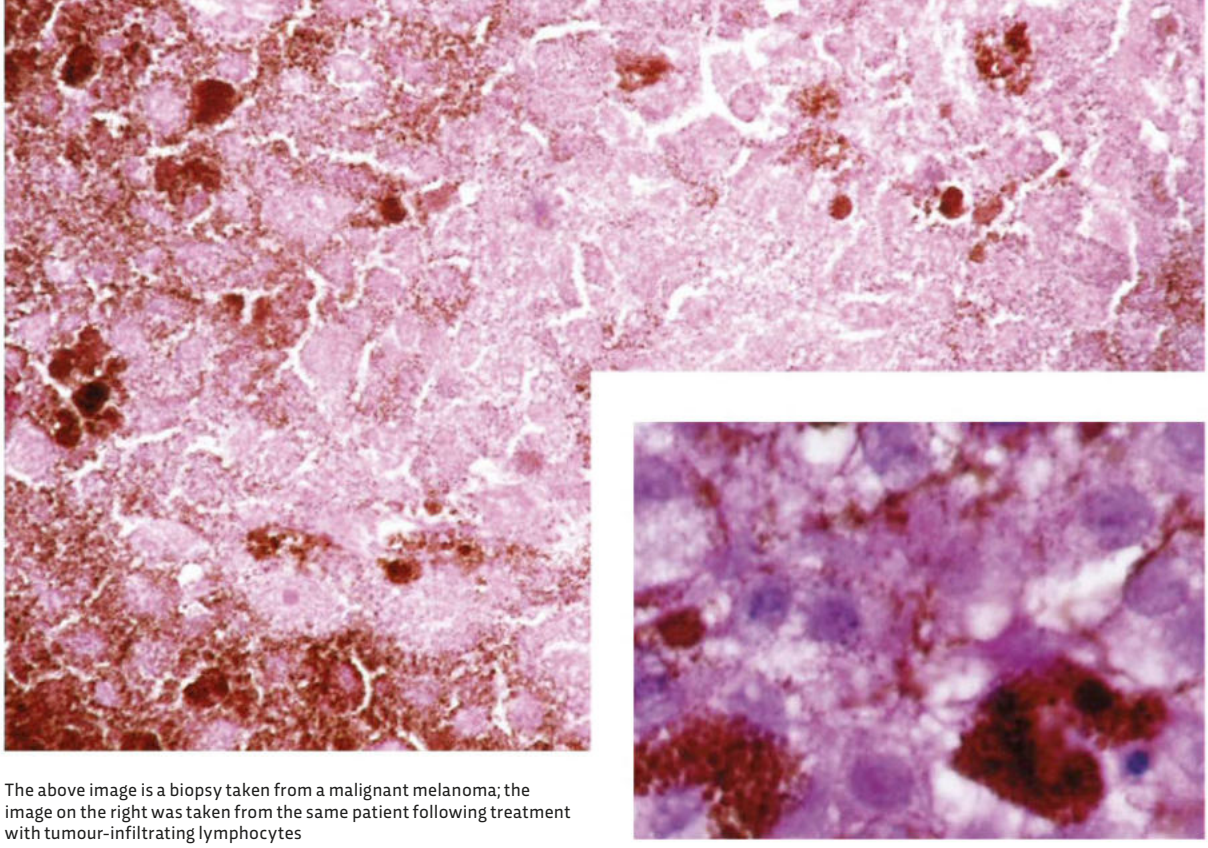
Since then, excitement at this game-changer has, if anything, grown. The technique involves taking the brakes off the immune system or introducing man-made antibodies to attack cancers.

Scientific trials have already shown this method to be extremely effective at treating particular forms of lung and skin cancer, with tumours in some cases completely disappearing.

Patients in England and Wales whose melanoma has spread around the body will become the very first in Europe to benefit from a powerful combination of immunotherapy drugs called nivolumab and ipilimumab. But the applications may be much wider than that. ▶



RIGHT: Activated T-cell attacking a tumour cell



The above image is a biopsy taken from a malignant melanoma; the image on the right was taken from the same patient following treatment with tumour-infiltrating lymphocytes

In September this year, for example, scientists from the University of London announced that the immunotherapy drug IMM-101 had extended the lives of people with advanced and metastasised pancreatic cancer from four to seven months, with some subjects surviving for up to three years. There were also no side effects reported.

Scientists from Sweden announced earlier this year that they had found new ways to prevent cancers concealing themselves from immunotherapy approaches, by activating immune cells (macrophages) within the tumour itself to make it more recognisable.

New knowledge of the ways in which cancers evolve, gained from analysing the DNA of hundreds of patients, is uncovering ways to precisely guide immune cells to all cancer cell types in a tumour. Researchers from the Cancer Institute at University College London (UCL) have discovered that as a tumour develops, its genetic faults are 'flagged' in proteins on its cells. And even though these faults are diverse, all cells show the 'flag' of its very earliest mutations. This paves the way for therapies that specifically activate immune cells that target all cancer cells, because they carry a common genetic flag.

"What better system to target the diversity of a tumour and its dynamic nature than the very system that has evolved over four billion years to do just that – the immune system?" says Swanton. "Trying to predict the future is impossible, but I'm very hopeful that in my lifetime we are going to see some magnificent changes in the management of this disease. But it's a massive challenge, and a battle of wits with evolution."

CANCER VACCINES

A jab that prevents cancer was once seen as an unrealistic Holy Grail. But, with advances in immunotherapy, the prospect of a cancer vaccine no longer seems the outlandish proposition it would have 10 or 20 years ago.

The human body's immune system often ignores cancer cells, because they are hard to distinguish from normal cells. But a new injection currently being tested in Germany smuggles cancer's genetic material (RNA) into the body via nanoparticle capsules. The nanoparticles appear similar to viruses, so the body's defence system is activated and taught to recognise and destroy cancer cells. The scientists believe that this research may eventually pave the way for a universal cancer vaccine.

Another type of vaccine is being trialled that could prevent recurrence of cancer in those patients who have already been treated for the disease. Researchers have found that a particularly potent type of immune cell called a tumour-infiltrating lymphocyte (TIL) can be harvested from a patient's tumour once it has been surgically removed. Analysis can reveal which of the TILs are active against the patient's own tumour, and these can then be injected back into the patient to minimise the risk of the cancer coming back.

The Centre Hospitalier Universitaire Vaudois, which is located in Lausanne, Switzerland, is currently building a new cell-processing facility to produce these personalised vaccines. George Coukos, the director of oncology at the hospital, believes that such treatments could transform the prospects of curing cancers of all types within 15 years.

"Immunology brings the prospect of drugs that are universal, to touch the majority of patients," explains Coukos. "In a decade we could be in a position where, for the first time, we could see a drastic reduction in the relapse rate, and therefore a drastic increase in the cure rate."





NEW TARGETING APPROACHES

Rather than pumping the whole body full of drugs, modern treatments can home in on cancer cells alone

Nanoparticles can be used to destroy tumours

PHOTOS: SCIENCE PHOTO LIBRARY X2

NANOPARTICLES AND LASERS

Danish researchers have developed new treatments in which nanoparticles are injected directly into the cancerous tumour. Lasers outside the body are then used to heat up the nanoparticles, burning the cancer cells from within. Unlike chemotherapy and radiotherapy, this treatment avoids damage to surrounding tissue.

We are already using nanotechnology to deliver medication to cancer patients. Drugs can be chemically bonded to nanoparticles, which accumulate in tumours and release their payload.

TROJAN-HORSE DRUG DELIVERY

Another new targeting system, which has been tested on prostate cancer cells, uses engineered stem cells to carry potent chemotherapy drugs direct to cancer sites. Researchers from Brigham and Women's Hospital in Boston say that these 'Trojan Horse' approaches provide new ways of treating cancer that has spread, without poisoning the whole body with chemotherapy drugs.

SALMONELLA HELPS OUT

Researchers at Swansea University are enlisting the help of *Salmonella* bacteria to carry anti-cancer weapons to the heart of tumours. *Salmonella* bacteria have a natural tendency to find their way to tumours, then invade and multiply. The research team has engineered the bacteria to be harmless to patients, so they can carry cancer-killing molecules to tumours.

Simon Crompton is a freelance journalist and editor who specialises in science and health.

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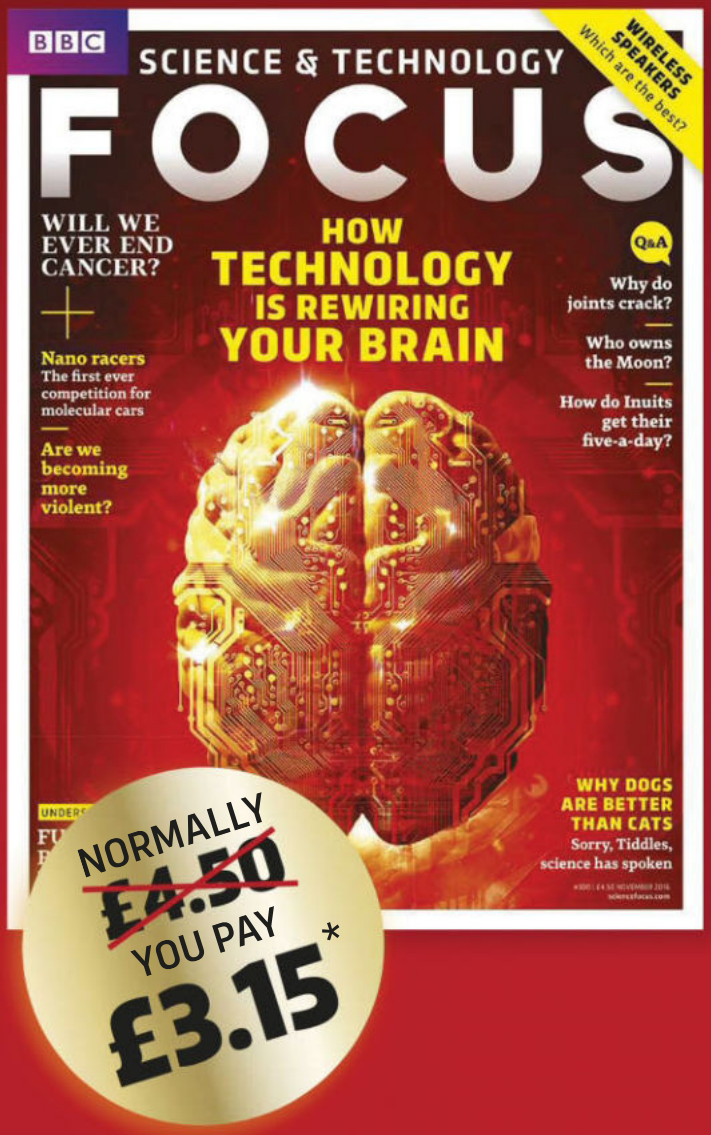
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YOUR DOGTOR WILL SEE YOU NOW

In the UK, 24 per cent of households own a pet pooch. While we know our furry friends are brilliant companions, could they actually be making us healthier too?

Words: **Dr John Bradshaw**

PHOTOS: ISTOCK


Ward K9
Keep you card on you at all times
Keep Card Visible
Dr Jack Russell
Osteology

Dogs: the universal stress-buster. That's the claim increasingly made for 'man's best friend' as dogs find their way into all kinds of unexpected medical situations. Last year, my own institution, the University of Bristol, teamed up with the Guide Dogs charity to offer stressed students a puppy play session. This was by no means the first of its kind: more than a thousand universities have put animal visitation programmes into place to help students. At Bristol University, the 600 slots quickly filled up. Yet the students' enthusiasm is supported by research. In one study, after as little as seven minutes' interaction with a friendly dog, students reported significantly less anxiety and greater feelings of contentment. Viewing a slideshow of the same dog for the same length of time had no effect on their mood. It seems that actually stroking and playing with the dog is crucial. Sorry, YouTube.

As well as stress, dogs are widely touted as a panacea for all kinds of ills such as high blood pressure, loneliness, heart disease and depression, to name but a few. A quick search of the internet will reveal countless articles extolling the health benefits of keeping pets. Some of these claims are supported by science, others remain to be investigated thoroughly, while a few seem to be little more than wishful thinking. So what does canine companionship really offer?

Stressed students clearly value the calming sensation of stroking a dog, and this effect is well supported by experiments. In this kind of research, a scientist will usually ask a person to read aloud to a stranger (which seems pretty tame compared to the sheer terror of an exam). Nevertheless, measurable reductions in stress have been recorded just by placing a dog in the same room as the subject. If stroking the dog is allowed, the reduction in stress is even greater. Moreover, it's not simply that the reader reports feeling less stressed, it's actually reflected in their physiology too: their blood pressure falls and their heart beats more slowly and rhythmically.

DIFFERENT STROKES

Long-term stress is a trigger for heart disease, so not surprisingly it's been suggested – and is now widely believed – that the relaxing effect of contact with dogs might benefit cardiovascular health over a lifetime. Early studies supported this idea, showing that dog owners were more likely to recover from heart attacks than people with no pets. However, the act of petting alone is unlikely to have been a major factor, since cat owners seem to be *more* susceptible to heart disease. Focus therefore shifted to the known benefits of taking regular moderate exercise,



BELOW: Dogs at universities have helped students de-stress

PHOTOS: BHAGESH SACHANIA/UNIVERSITY OF BRISTOL, GETTY

THE MAKING OF MAN'S BEST FRIEND

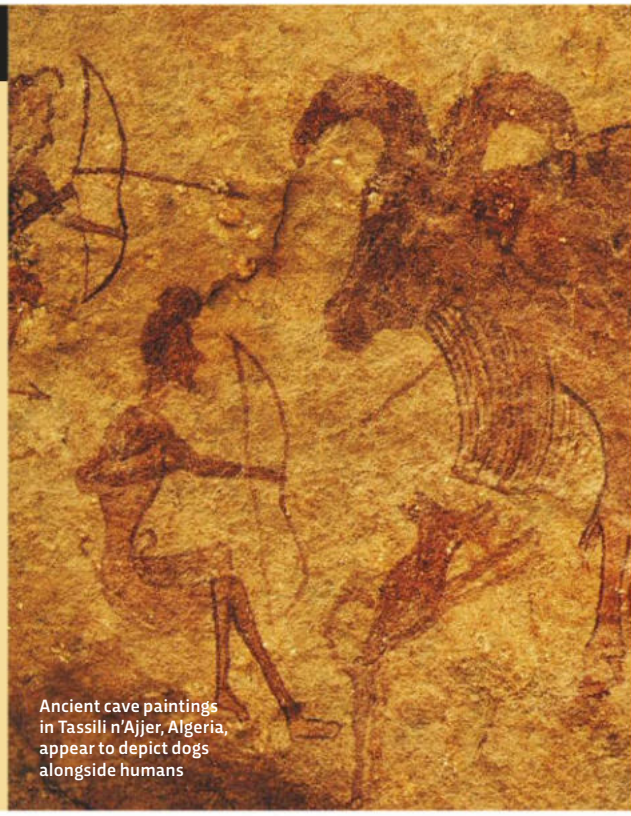
Can we tell when dogs were first domesticated?

When and where dogs were first domesticated is still hotly debated among scientists. There are a few hard facts that all agree on: dogs were once wolves (and not jackals, as Austrian zoologist Konrad Lorenz once maintained) and they were the first animal to be domesticated, some time in the late Pleistocene before the dawn of agriculture. Beyond that, there is little agreement. The earliest archaeological remains that are unequivocally dogs and not wolves date from 14,000 years ago, but 30,000-year-old skulls have been discovered in France and Belgium that are not pure wolf and may be dogs.

With such baffling archaeological evidence, most scientists have turned to DNA to find out when and where dogs were first domesticated. Tens of thousands of blood samples have been taken from street dogs around the world, for comparison with those of wolves. It's even possible to analyse DNA from ancient bones: minute samples from the 30,000-year-old skulls mentioned earlier are currently being studied, and it has already been shown that ancient dogs preserved in the Alaskan permafrost were descended from Asian wolves, not American ones.

Indeed, the ancient DNA may turn out to be more informative than the DNA of living dogs. Because dogs have been carried hither and thither around the world, for thousands of years, their current distribution may tell us very little of their origins – hence the competing claims of different groups of scientists that dogs variously originated in eastern Asia, Mongolia, Siberia, Europe or Africa.

But *why* were the animals domesticated in the first place? The most recent theory is that dogs domesticated themselves, initially living as scavengers in and around our villages. Today, this is a way of life still shared by three-quarters of a billion unowned dogs worldwide.



Ancient cave paintings in Tassili n'Ajjer, Algeria, appear to depict dogs alongside humans

A 20-YEAR-OLD MAN WAS MORE SUCCESSFUL IN OBTAINING YOUNG WOMEN'S PHONE NUMBERS IF HE HAD A DOG AT HIS SIDE

which many dog owners do. Not all, of course: a surprising number of pet dogs get their only exercise in their owner's back garden. Moreover, many dog walkers seem more interested in their smartphones than what their dog is up to, and are therefore unlikely to walk sufficiently fast to enhance their cardiovascular health.

It's been claimed that dog owners get more exercise walking their pet than someone who takes out a gym membership. But perhaps that's not much of a claim, since over half of people who take out an annual gym subscription in January have stopped going by April. And even though some dog owners undoubtedly do take more moderate exercise than people with no dog to walk, this doesn't seem to translate into their living any longer. Perhaps dog ownership, compared with a brief encounter with a dog cared for by someone else, is stress-neutral: the daily routine of exercising the dog may be relaxing, but owning an animal can be stressful, particularly if it is disobedient or prone to illness.

Recently, the American Heart Association has stated that dog ownership is "probably associated" with a reduced risk of heart disease. Since this doesn't seem to translate into dog owners living longer, there may be another explanation. It could be that it works the other way around: people with poor health think twice before embarking on the responsibility of caring for a dog for the next 15 or so years. Perhaps they get a cat instead, which would account for the generally poorer health of cat owners compared to the rest of the population.

WORKING DOGS

Dogs can do more for their owners than just get them outdoors: they also provide companionship to a degree unmatched by any other animal. Some dog owners even like to take their pets into the office. In fact, campaigns to persuade companies to allow dogs in the workplace have been gathering momentum since the turn of the millennium.

While office workers' stress levels generally increase from the beginning to the end of the working day, studies have shown that if employees are allowed to bring their dogs in, they actually feel less stressed by the end of the day. It's unclear how co-workers feel about sharing their space with other people's animals, but anecdotally it seems as though a dog can reduce tensions by providing a focus for conversation.

Several studies have confirmed that dogs do indeed bring people together. In one, conducted in France, it was found that a 20-year-old man was far more successful in obtaining young women's phone numbers if he had a dog at his side: fewer than one in ten complied if he was on his own, one in three if he was with the pooch.

While there are certain drawbacks to bringing dogs to work, including complaints from those ▶

DOG MYTHS BUSTED



OLD DOGS CAN'T BE TAUGHT NEW TRICKS

Nonsense. Like all animals, dogs find it easier to learn while they're young, but their brains are still capable of altering established patterns of behaviour, well into middle age.



DOGS HAVE A BETTER SENSE OF SMELL THAN CATS DO

Yes and no. If we're talking about the dog's actual nose, then it is 10 to 100 times more sensitive than a cat's. But both cats and dogs have a second 'nose' called the vomeronasal organ, and the cat's is the more sensitive.



DOGS CAN FEEL GUILTY

Nope, their emotions are probably restricted to simple 'gut feelings' like joy, anger, fear and anxiety. The clues that owners interpret as a dog's 'guilty look' are actually signs that the dog is anticipating punishment, but doesn't know what it's done wrong.



DOGS PREFER CANINE COMPANY

Wrong again. Given the choice, most dogs prefer to spend time with people, and become distressed when their owners leave the house. Therefore, taking dogs to work probably benefits them even more than their owners.



A HEALTHY DOG ALWAYS HAS A WET NOSE

Partly true. While a dry nose may be a sign of illness or dehydration, it may also be because the dog has just woken up and not licked its nose yet.



DOGS NEED TO BE 'KEPT IN THEIR PLACE'

No. Current scientific thinking on dogs' minds indicates that they are highly unlikely to have any concept of their position within the family hierarchy. Furthermore, although physical punishment used to be a staple technique in dog training, studies have shown that it creates disobedient and anxious dogs.



Forever friends: 12,000-year-old skeletal remains of a human and dog, photographed in Israel

with allergies, and conflicts with religious beliefs, they do seem to bring about a general lightening of mood.

PAWS FOR THOUGHT

So, it appears that dogs build bridges between people and make their owners seem more trustworthy. These may be the main benefits that dogs provide for veterans of conflict who suffer from Post Traumatic Stress Disorder (PTSD) and other mental health difficulties. Although it has been suggested that all veterans should have dogs, some find dog ownership too difficult. Trained PTSD dogs will bring the same stress-reducing benefits as any dog, but to be effective they also need to be trained to respond to the needs of their owner, whether that's waking them from nightmares, bringing medicines, or leading them to safety when they experience a panic attack.

A dog's capacity to bring people together may also explain their effectiveness in many kinds of therapy, including the benefits that dogs bring to nursing homes, especially to those institutions that care for individuals suffering from dementia. In one recent Italian study, scientists examined the reactions of

PHOTOS: GETTY X7, ISTOCK



THERE IS EVIDENCE THAT SOME CHILDREN WITH AUTISM-SPECTRUM DISORDERS BENEFIT FROM THE COMPANY OF A DOG

dog-loving residents to regular half-hour sessions with therapy dogs. Playing with the dogs brought about a remarkable change in the residents' behaviour. They went from being largely apathetic to become more active and animated, but also more spontaneous with the dogs – for example, throwing a ball for the animals to retrieve. Another notable feature of interaction with dogs is the extent to which elderly residents reach out and touch them, reducing their feelings of emotional isolation. Unfortunately, although claims have been made that contact with dogs might improve mental functioning, no such benefits have been detected.

There is evidence that some children with autism-spectrum disorders benefit from the company of a dog. Some such children form intense relationships with animals, seemingly finding them easier to relate to. One recent study from France indicated that to be effective, the dog has to be obtained when the child is old enough to interact with it: such children tend to ignore pets that were there when they were a baby.

But dogs really come into their own when they can combine their outgoing natures with their incredible ability to read our body language – and their ultra-sensitive noses. Seizure Alert Dogs are now being trained to assist people with metabolic conditions such as brittle diabetes and Addison's disease, but the original idea came from the dogs themselves, some of which seem to have taught themselves to alert their owners to an impending attack. It's not known precisely how they do this, but a dog's ability to detect minute changes in the body odour of the subject must play a part.

The relationship between us and dogs has been in existence for over 10,000 years, and shows no signs of weakening. But it is changing, as the traditional tasks that dogs performed have been supplemented by new roles. Getting a dog may not automatically make you healthier, but if you train it well it will undoubtedly make you happier – and encourage you make new friends.

Dr John Bradshaw is an anthrozoologist based at the School of Veterinary Sciences at the University of Bristol.

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FROM THE MAKERS OF BBC FOCUS MAGAZINE

THE AMAZING BRAIN



In this special issue, the editors of *BBC Focus Magazine* reveal the extraordinary abilities of your brain, the latest research into mental health, and how we can make ourselves smarter in the future.

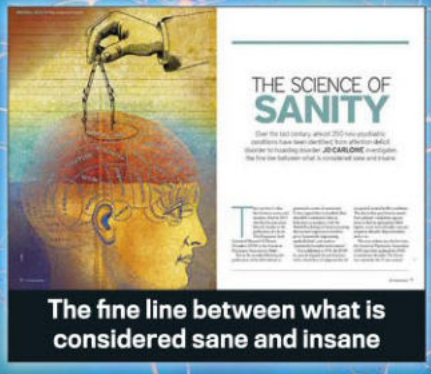
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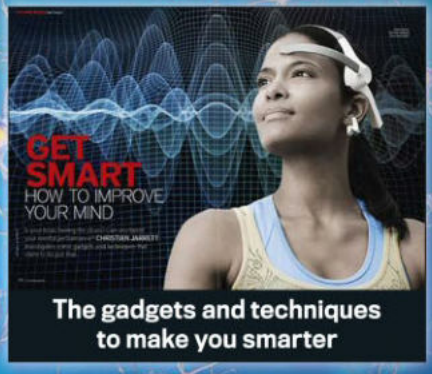
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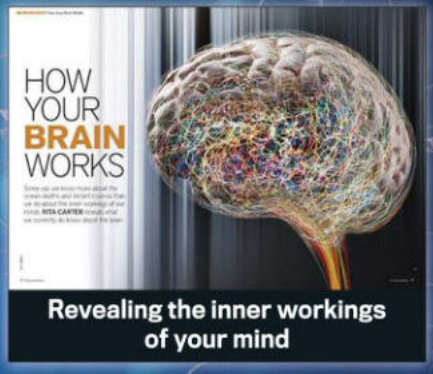
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The fine line between what is considered sane and insane



The gadgets and techniques to make you smarter

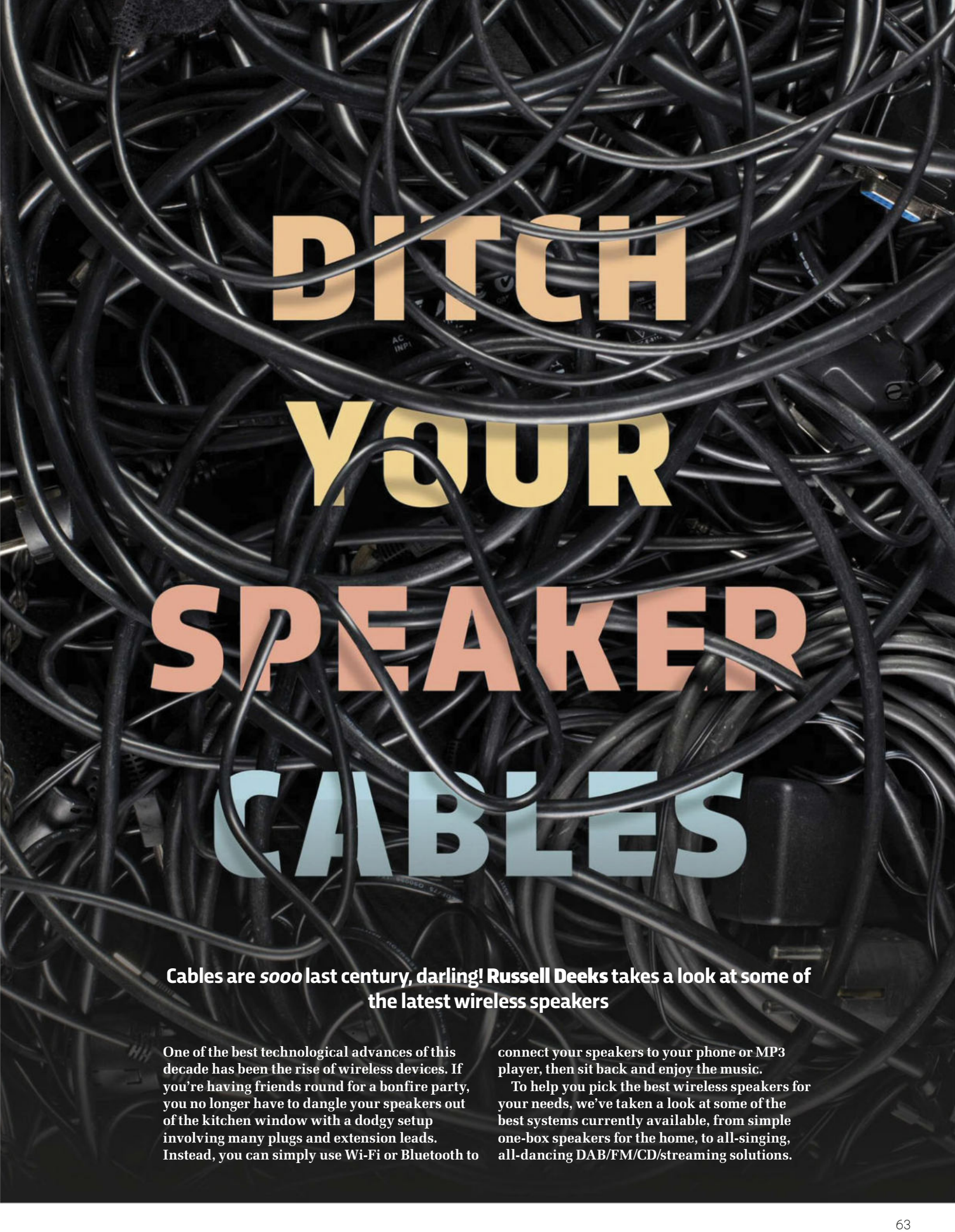


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DITCH YOUR SPEAKER CABLES

Cables are *sooo* last century, darling! Russell Deeks takes a look at some of the latest wireless speakers

One of the best technological advances of this decade has been the rise of wireless devices. If you're having friends round for a bonfire party, you no longer have to dangle your speakers out of the kitchen window with a dodgy setup involving many plugs and extension leads. Instead, you can simply use Wi-Fi or Bluetooth to connect your speakers to your phone or MP3 player, then sit back and enjoy the music.

To help you pick the best wireless speakers for your needs, we've taken a look at some of the best systems currently available, from simple one-box speakers for the home, to all-singing, all-dancing DAB/FM/CD/streaming solutions.

KEEP IT SIMPLE

Simple solutions for streaming audio from your phone, tablet or desktop



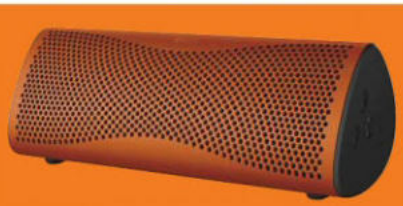
Harman Kardon Go+Play

£249.99, harmankardon.co.uk

We couldn't decide at first whether this should go here or in the portable speakers section (see right). It does, after all, feature a rechargeable battery that'll give you eight hours' use off a single charge. But it ended up here for three reasons. First, at just shy of 3.5kg it's a bit heavy to lug around easily. Second, it's covered in fabric that might pick up grass stains if you took it to the park, particularly if you opted for the white version rather than the black model shown here.

Third – and most importantly – the Go+Play just sounds too damn good to be relegated to your camping kit! Pumping out 4x 25W through two 90mm woofers and two 20mm tweeters, Go+Play provides lashings of rich, warm bass but the highs and mids remain beautifully crisp and detailed.

It's a Bluetooth machine, which means pairing with your device is simplicity itself. It can maintain open connections with up to three devices at a time, eliminating faff if different family members all want to use it, and opening up the potential for post-pub DJ showdowns with your mates.



Kef Muo

£249.95, uk.kef.com

Though portable enough to carry around – it measures just 80 x 210 x 60mm, and weighs a mere 0.8kg – this miniature Bluetooth model from Kef is good enough for use in the home too. If you're quick, you might still grab one of the 300 limited-edition models in spectral colours.

B&W Zeppelin Wireless

£499, bowers-wilkins.co.uk

Back in the docking station era, B&W was one of the first hi-fi companies to get in on the one-box speaker game with its acclaimed Zeppelin. This year, the landmark product has had a streaming-era update, and it's sounding just as great as it always did.



Monitor Audio Airstream S200

£149, monitoraudio.co.uk

At the more affordable end of the market, this speaker offers plenty of audio bang for your buck and can work via both Bluetooth and Wi-Fi for maximum flexibility, even if it does look a bit too much like a traditional computer speaker for our liking.



ON THE MOVE!

Rugged, portable speakers let you have music wherever you go

Minirig 2.1

£369.99, minirigs.co.uk

Like the Harman Kardon Go+Play, this is another speaker that could have gone in either the 'Keep it simple' or the portable category. But while the sound that comes out of the two diminutive Bluetooth speakers and accompanying subwoofer is certainly good enough for in the home, writing about it as a domestic product would underplay the fact that Minirig has come up with arguably the world's first truly portable subwoofer. What's more, each speaker comes in its own padded carry case made of hard-wearing ripstop nylon, so you've no need to worry about bumps and scratches as you lug it from beach to festival to barbecue.

The system can be set up to work without cables, though we found it was quicker, and no great inconvenience, to link the speakers together using the supplied 3.5mm jack cables. And once we did, the sound that came out blew us away. The Minirig 2.1 perhaps lacks just a little of the top-end precision of the Go+Play, but it's still a big step up from the vast majority of other portables, and there's certainly no lack of bottom-end grunt. Despite their tiny size (each of the main speakers measures just 102mm across and stands 73mm high, while the sub is 102mm across and 219mm long), we'd happily rely on these speakers to drive a fair-sized gathering outdoors.

Oh, and all the speakers are available in a choice of seven colours. What more could you want?





Dali Katch

£330, dali-speakers.com

This elegant and lightweight speaker from Danish company Dali is eminently portable and pumps out 2x 18W of sound. It's billed as "the audiophile's Bluetooth portable" and it lives up to such claims, though it's perhaps more suited to jazz and classical buffs than serious bassheads.

Lava BrightSounds

£39.99, lavaaccessories.co.uk

Coming from the budget end of the spectrum, this speaker isn't the loudest or most detailed out there. On the plus side, it looks great, comes in four colours, is waterproof, and doubles up as a camping light and a powerbank for your phone or tablet. Not bad for under £40!





House Of Marley Bag Of Riddim

£299.99, houseofmarley.co.uk

House Of Marley makes a wide range of Bluetooth portables. Many are shaped like little bongo drums, but we were particularly taken by this four-speaker offering that comes in its own hemp, cotton and recycled plastic carry-bag.

ROCKIN' ALL OVER THE HOUSE

Multi-room systems to fill your home with music

Sonos Play:5

£429, sonos.com

Sonos is far and away the market leader when it comes to multi-room systems. We tested the entry-level Play:1 (£169), and there's the £259 Play:3 as well, but it's the Play:5 that's the flagship and it beautifully demonstrates why Sonos is so popular. We'd strongly suggest that if you've got the money, it's worth the extra investment to really give your ears a treat.

Sonos products work via Wi-Fi rather than Bluetooth, so you'll need to connect at least one speaker to your router via an Ethernet cable. However, you can also add a Sonos Bridge hub that acts as a relay, if your router's in a less than speaker-friendly position. Plus, this is very much an ecosystem, so you'll also need to install Sonos's controller software on any phone, tablet or laptop you want to use with it. This all means that setup is a little more complicated than most other products here, but once you've got over the initial fiddling, adding extra components is a doddle. Ultimately, we reckon the sheer joy of controlling all the music throughout your house from a single tablet is well worth the effort.



Bluesound Vault 2 & Pulse subwoofer

£1,000 + £600, bluesound.com



Bluesound's multi-room systems represent a serious challenge to Sonos's domination, with support for streaming lossless audio and a wide variety of components to choose from. If you're a stickler for sound quality, it's a tough choice to make.

Denon HEOS

From £199, denon.co.uk

Denon has also launched its own multi-room wireless system. Like Sonos and Bluesound, it's a full-blown ecosystem in its own right, with speakers ranging from £199 to £599, all controlled from an app and with support for lossless formats.



Bose Soundtouch 10

£169.95, bose.co.uk

Launched last year, the Soundtouch 10 finally brought streaming to the long-established Soundtouch range. The one-box speaker streams audio via Bluetooth and Wi-Fi, and you can add extra speakers to create a DIY multi-room system without too much hassle.



ALL-SINGING, ALL-DANCING

Speakers that do more than just stream music

Orbitsound BAR A70

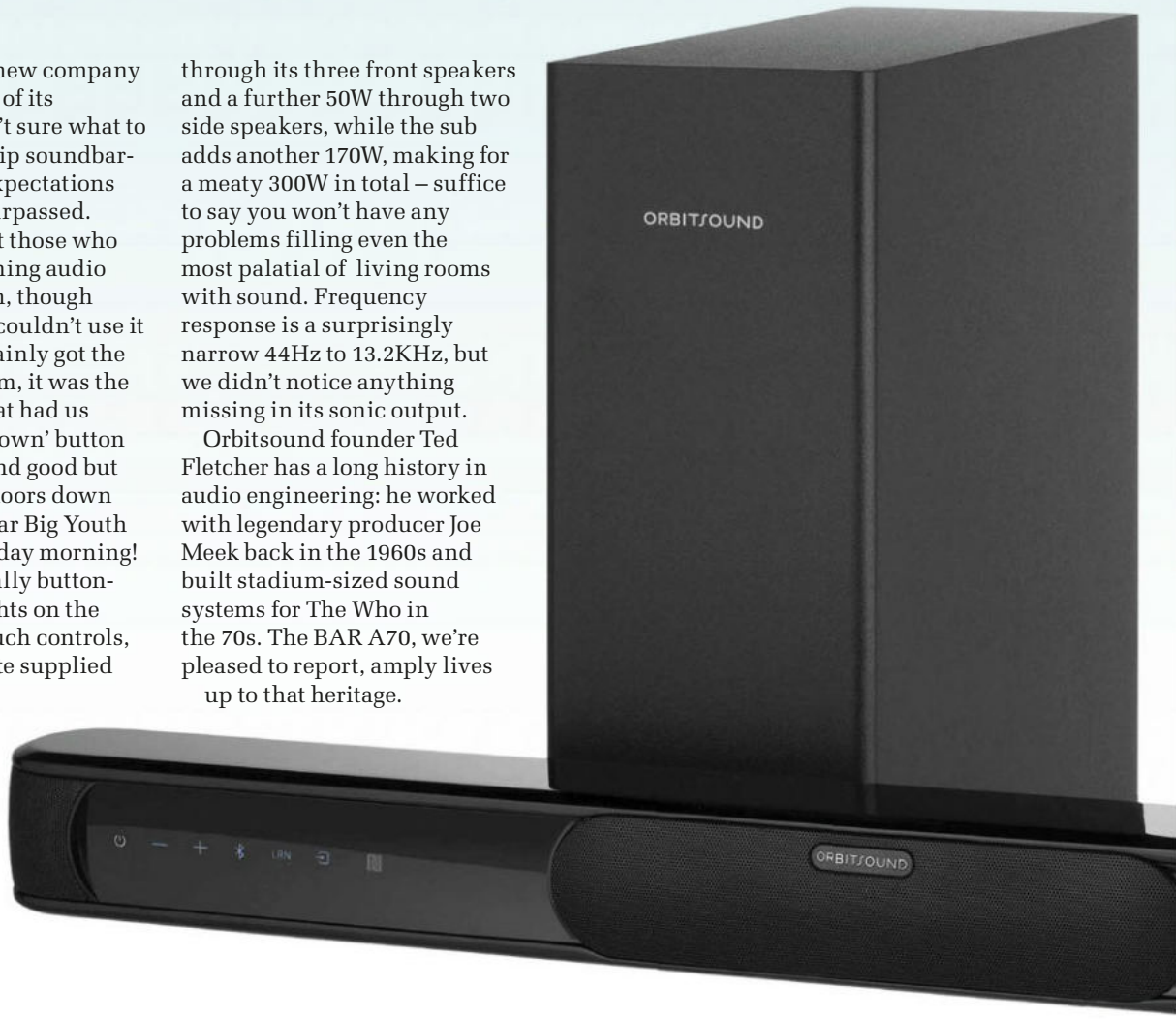
£499.95, orbitsound.com

Orbitsound is a relatively new company and, not having tested any of its products before, we weren't sure what to expect from its new flagship soundbar-and-sub combo. But any expectations we did have were easily surpassed.

The BAR A70 is aimed at those who want to incorporate streaming audio into a home cinema system, though there's nothing to say you couldn't use it purely for music – it's certainly got the chops. As a powered system, it was the only speaker in our test that had us reaching for the 'volume down' button – not because it didn't sound good but because the people three doors down probably didn't want to hear Big Youth blasting at 10am on a Tuesday morning!

The soundbar is essentially button-less, with the indicator lights on the front panel doubling as touch controls, though there's also a remote supplied that'll save you having to traipse across the room the adjust the settings, as well as reducing the amount of fingerprints you have to wipe off. The soundbar itself pumps out 80W through its three front speakers and a further 50W through two side speakers, while the sub adds another 170W, making for a meaty 300W in total – suffice to say you won't have any problems filling even the most palatial of living rooms with sound. Frequency response is a surprisingly narrow 44Hz to 13.2KHz, but we didn't notice anything missing in its sonic output.

Orbitsound founder Ted Fletcher has a long history in audio engineering: he worked with legendary producer Joe Meek back in the 1960s and built stadium-sized sound systems for The Who in the 70s. The BAR A70, we're pleased to report, amply lives up to that heritage.





Denon CEOL N9

£329, denon.co.uk

You can't argue with the versatility of this receiver-and-speakers combo, which offers streaming via Bluetooth and Wi-Fi, with support for all popular file formats including FLAC and 24-bit WAV, as well as a built-in CD player and an FM/AM tuner.

Geneva Model S Wireless DAB+

£329, genevalab.com

This one-box solution offers FM and DAB radio and a digital clock as well as Bluetooth streaming in one rather elegant package. Sound output is a respectable 30W with a frequency range of 75Hz to 20kHz. It's available in white, red or black so you can choose the unit that suits your decor.





Onkyo TX-8150

£550, onkyo.co.uk

If you already have a set of home cinema speakers and you want to add streaming audio to the mix, this AV receiver supports Bluetooth and Wi-Fi streaming of MP3, WAV and lossless files as well as Spotify and Tune-In radio.It even has built-in FM and DAB tuners to boot. F


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HELEN CZERSKI... WHY MICROWAVE OVENS ARE WEIRD

"SOME BOWLS COME OUT BLISTERINGLY HOT, BUT OTHERS COME OUT AS COOL AS A CUCUMBER"

Microwave ovens are weird. We put food in, press a button, and a short time later the food is hot, even though nothing has touched it. Even weirder is that microwaves don't work for everything: they're fantastic for water (this is how they heat food), but plastic and wood are unaffected. And then there are ceramics. Some bowls come out of the microwave blisteringly hot, and I worry about whether they're going to explode in some horrendously messy way. But others come out as cool as a cucumber (and significantly cooler than a cucumber that's been in a microwave). How can materials that look identical behave so differently?

What microwave ovens are best at is heating water. A microwave is a type of light, but it's far less energetic than the visible light we can see. The waving in a light wave is being done by electric and magnetic fields. In a microwave oven, these fields oscillate back and forth about 2.5 billion times a second. The trick to the heating is that water molecules are strongly polar, which means that some parts of the molecule are electrically positive and some are electrically negative. As the microwaves whoosh past, the water molecules try to line up with the changing electric field of the waves, twirling around so that they line up one way and then the other, pirouetting at the frequency of the wave. As they twirl, they bump into the molecules around them, giving away their twirling energy, and so it becomes heat.

This is the key to any question about what a microwave does and doesn't heat up. If you've got polar molecules that can move, they'll try to twirl. Ice isn't heated by microwaves because although the molecules are polar, they're locked in place and can't move. Sugar and fat are weakly polar molecules, so they'll get hot but not as efficiently as water.

There's a simple way to find out whether something has the right sort of polar molecules in it. Put your test object in the microwave next to (but not touching) a cup of cold water and microwave it on high for a minute. If it's got the right sort of molecules, your test object will get hot. If it doesn't get hot, then it's transparent to microwaves – they'll just go straight through as though it wasn't there. I spent an evening testing the contents of my cupboards. None of the mugs and bowls got hot, but a jam jar definitely got warm.



Jam jars are made from soda lime glass, and this absorbs a bit of microwave energy. However, the clay used to make pottery is transparent to microwaves, so doesn't heat up. But it turns out that two things could change that. Earthenware (different to stoneware or porcelain) is fired at a lower temperature, and so the finished item may still have some water molecules in it, which can heat up. And certain glazes used to decorate the ceramic may absorb microwaves, and share that heat with the rest of the object.

Further tests made me suspect that the reason my bowls get so hot is that they're unusually good at conducting heat, so once the food gets very hot, they do too. They're actually perfectly microwave-safe (I feel better for having checked). But now I know that I can use my kitchen microwave as a test for the type of molecules that make up an object.

I will never see the pirouetting molecules directly, but I can feel the consequences of their dance. Reheating soup is never going to be the same again!

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, will

NEXT ISSUE: WHY DON'T FLAMBÉD CRÊPES CATCH FIRE?

ILLUSTRATION: DARIA SKRYBCHENKO



PARTICLE ZOO

Everything on Earth is made up of atoms. Atoms themselves are made up of particles, while force-carrying particles hold everything in the right place. By deciphering the particles and their associated force-carriers, physicists have gained a deeper understanding of how the Universe works.

PHOTO: GETTY

HOW DO WE KNOW...

WHAT MATTER IS MADE FROM?

Stars, skyscrapers, seaweed… everything is made from the same unimaginably tiny objects. We delve into the strange world of particle physics

WORDS: **PROF JON BUTTERWORTH**

Matter. Stuff. Everything we can see is made from atoms, each with electrons surrounding a tiny nucleus. And inside the nucleus are protons and neutrons, each made of quarks. Add a horde of neutrinos flying around us, elusive and insubstantial, and that's where it stops. So says the Standard Model of particle physics, the best theory we currently have for explaining what all the visible matter in our Universe is made from.

But how do we know this? Much of our knowledge comes from scattering experiments – that is, bouncing one thing off another. We have discovered new elements, and new fundamental particles, by carrying out scattering experiments at high-energy particle accelerators around the world. But scattering isn't the only way to find out what the Universe is made of… our story begins in a Manchester lab at the beginning of the 19th Century.

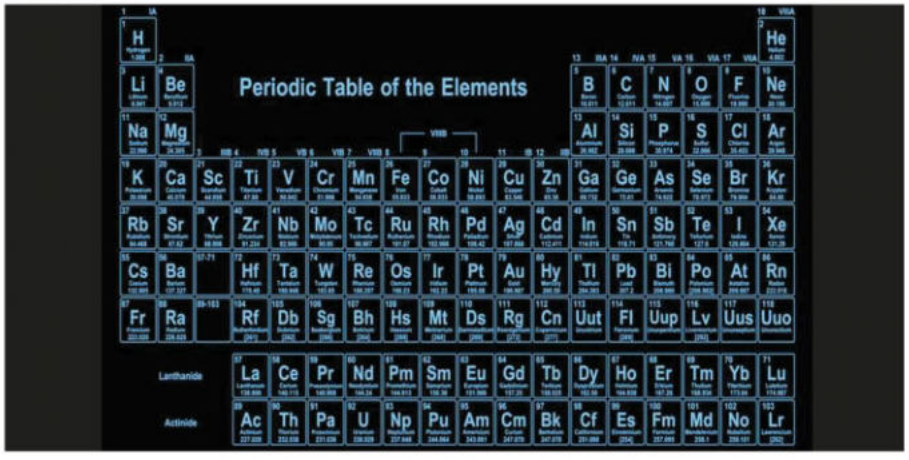
What's the matter?

John Dalton is widely considered as the father of atomic theory. As a chemist, physicist and meteorologist working in Manchester, he measured the weights of materials involved in various chemical reactions, and showed that different elements always combined in fixed ratios. This was consistent with the idea that there existed a smallest unit of any chemical element – the atom – that makes up everything we see around us.

More elements, and hence types of atom, were discovered over the following years, and in 1869 Russian chemist Dmitri Mendeleev made a major breakthrough by arranging them into the periodic table, according to their chemical and atomic properties.

While the order and predictability of the chemical elements was good evidence for the existence of atoms, scientists wondered if there could be even smaller particles. In 1897, physicist JJ Thomson was studying 'cathode rays' at Cambridge University. Cathode rays are emitted by a hot metal and are accelerated by electric and magnetic fields. Thomson discovered that the cathode rays were made up of tiny particles, much lighter than an atom and of the same charge and mass, no matter what metal was used in his experiment. These were electrons, the first subatomic particles to be discovered.

It was thought that these particles were present inside the atom. But as the electrons appeared to be so light, it was assumed that there must be other stuff within the atom to account for most of its mass. It was not known ➤



Elements on the periodic table are arranged according to their chemical and atomic properties

PHOTO: SCIENCE PHOTO LIBRARY



Hans Geiger and Ernest Marsden established that most of an atom's mass is concentrated within a tiny nucleus

what this other stuff might be, or how the electrons might be distributed among it.

One idea, proposed by Thomson, was that the electrons were distributed throughout the atom like raisins through a plum pudding. Surprisingly, plum puddings don't have any plums in them, but this is nothing compared to the surprise received by Hans Geiger and Ernest Marsden – two physicists working in Manchester under the direction of Ernest Rutherford. To try and understand subatomic structure, they fired a beam of alpha particles (see glossary) at gold foil. They were expecting the particles to pass straight through, but some of them bounced back. It was a result that Rutherford famously described as like firing a 15-inch shell at a piece of tissue paper and it coming back to hit you. This could only be explained if the overwhelming majority of the atom's mass was concentrated in a volume thousands of times smaller than the atom itself. This is indeed the case – this dense concentration is the atomic nucleus.

The lightest atomic nucleus belongs to hydrogen. Its nucleus consists of a single proton, which can be exposed by removing the single electron from the atom. Scientists measured the mass and charge of various nuclei, and came up with a problem: if the nucleus purely consisted of protons, then this would leave the atom having too much positive electric charge.

More than meets the eye

James Chadwick – another physicist working for Rutherford – was one of those convinced that there must be another kind of particle in the atom, with a mass about the same as the proton but with zero electric charge. In 1932 he discovered it. This was no easy task, since most of the methods for detecting particles relied upon the fact that they knock electrons off other atoms. This leaves a charged particle (ion) that can be easily detected using a device called a cloud chamber. As neutrons have no charge, they cannot be detected in a cloud chamber.

Chadwick got around the problem by exploiting the fact that neutrons have almost the same mass as a proton, which means that they'll effectively transfer their energy, in much the same way as a fast-moving cue ball transfers its energy to a stationary snooker ball. So Chadwick fired neutrons – produced when beryllium was bombarded by alpha particles – into various materials containing protons, and detected the protons when they emerged from the other side. This told him that the mysterious beam coming from the beryllium indeed consisted of neutral particles of similar mass to the proton – the sought-after neutron.



Artist's impression of cosmic rays hitting the Earth's atmosphere, creating a shower of subatomic particles

GLOSSARY

Alpha particle
These are helium nuclei – two protons and two neutrons bound together. They are produced in many radioactive decays.

Beta decay
The decay of an atomic nucleus, which involves the transition of a neutron into a proton.

Boson
The forces of the Standard Model are all carried by particles called bosons.

Gluon
These are a type of boson that carry the strong force. They 'glue' quarks together.

Hadron
A particle made of quarks and/or antiquarks.

Lepton
A particle that does not feel the strong force. Electrons and neutrinos are leptons.

Photon
The carrier of the electromagnetic force.

Quark
A particle that is bound inside hadrons by the strong force.

Strong force
This force binds the atomic nucleus together, and confines quarks inside hadrons.

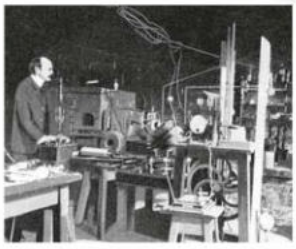
Weak force
The short-range force responsible for beta decay.

PHOTOS: GETTY, SCIENCE PHOTO LIBRARY X2

TIMELINE: PARTICLE PHYSICS

Our quest to understand matter has stretched some of science's greatest minds

1897



1897
JJ Thomson shows that the 'rays' emitted in a cathode ray tube are tiny particles, 2,000 times lighter than a hydrogen atom. The subatomic particles are electrons.

THEODOR WULF (1868-1946)

This German Jesuit priest and professor of physics at Ignatius College in Holland developed one of the first detectors for atmospheric radiation, which he used to discover cosmic rays.

ERNEST RUTHERFORD (1871-1937)

This New Zealand born physicist completed his most famous experiments in Manchester before becoming head of the Cavendish Laboratory in Cambridge during a golden period of breakthroughs.



1928



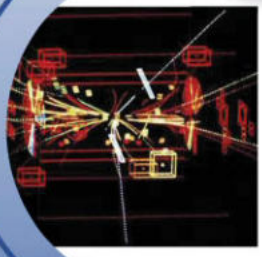
1928
Paul Dirac devises an equation capable of describing electrons moving at 'relativistic' speeds close to the speed of light. The equation predicts the existence of antimatter, discovered four years later.



CHIEN-SHIUNG WU (1912-1997)

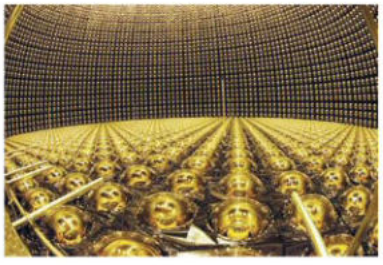
This Chinese American physicist made the key observation that the weak force has 'handedness' it cares about the difference between left and right. This had a profound impact on the structure of the Standard Model.

1973



1973
The electrically neutral component of the weak force is discovered at CERN's Gargamelle experiment, CERN. This brings together the electromagnetic and strong forces the core of the Standard Model.

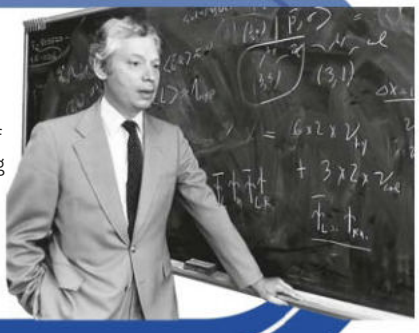
1998



1998
Neutrinos, long thought to be massless, are discovered to have mass by scientists working at the Super Kamiokande neutrino observatory in Japan. The Standard Model is forced into its first fundamental change.

STEVEN WEINBERG (1933-)

This US physicist was a key figure in the development of the Standard Model, winning a Nobel Prize for his work in combining the theories of electromagnetism and the weak force.





GERARDUS 'T HOOFT (1946-)

This Dutch physicist based at Utrecht University made a crucial contribution to the Standard Model by proving that the theory is able to make precise predictions without giving infinite answers.



2012
The Higgs boson is finally discovered at CERN, proving the existence of the 'Higgs field' that gives fundamental particles their mass.

2012

PHOTOS: GETTY X4, CERN X2, ALAMY, UNIVERSITY OF TEXAS, WAMMES WAGGEL/WIKIPEDIA



Particles that make up hadrons were dubbed 'quarks' by Murray Gell-Mann

THE KEY EXPERIMENT

Scientists: Jerome Friedman, Henry Kendall and Richard Taylor

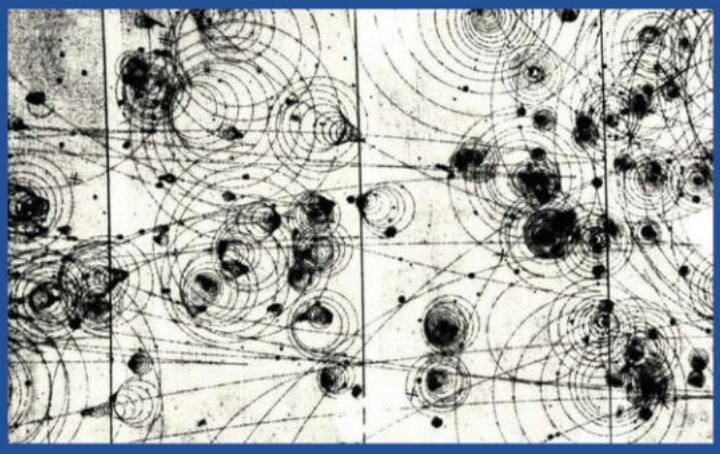
Date: 1967-1973

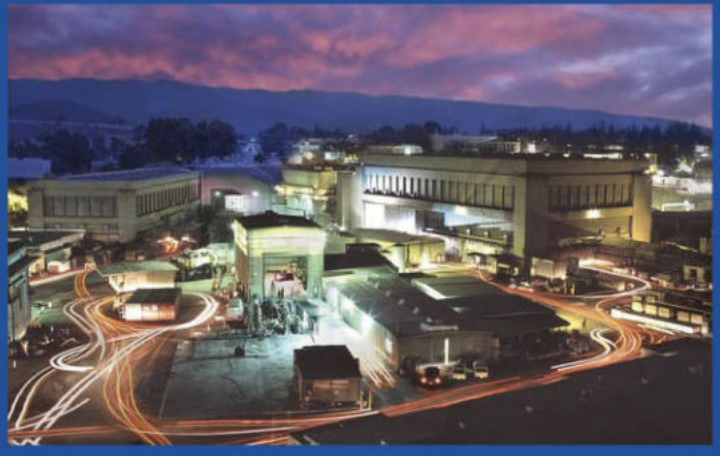
Discovery: Hadron particles are made of quarks

Prior to 1964, physicists were becoming increasingly concerned about the number of 'fundamental' particles they were discovering. Starting with the proton and neutron, many particles – generically called 'hadrons' – were appearing in experiments at accelerators and in observations of cosmic rays. Most were very short-lived, eventually decaying away to leave protons, electrons and neutrinos.

In 1964, Murray Gell-Mann and George Zweig, working independently at Caltech and CERN, showed that many properties of hadrons could be explained by different combinations of smaller objects, which Gell-Mann called quarks. Whether this was a mathematical trick, or whether hadrons actually contained quarks, remained open until a series of experiments by Jerome Friedman, Henry Kendall and Richard Taylor took place between 1967 and 1973 at the Stanford Linear Accelerator Center in California.

In these experiments, electrons were scattered off protons at energies high enough to penetrate the proton and break it up. From the energies and angles of the scattered electrons, it was possible to show the presence of tiny, hard objects inside the proton, with all the properties expected of quarks. We now know that there are six, apparently fundamental and infinitely small, types of quark, from which all the hadrons are made. It was a big leap forward in our understanding of matter, and a key step towards today's Standard Model.





TOP LEFT: Particles were detected via tracks of bubbles in superheated liquid

BOTTOM LEFT: The Stanford Linear Accelerator Center, where scientists first established that hadron particles are made up of quarks

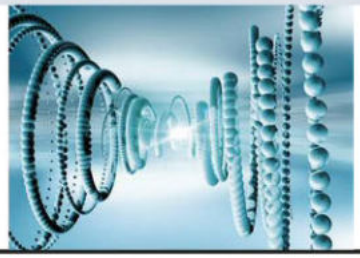
At this point, the basic constituents of matter seemed to be known. With protons, neutrons and electrons you could build every element in the periodic table, and with those elements you could build anything. But the way the particles interacted was not understood. For example, how could a bunch of protons, which were all positively charged and therefore ought to be repelled from each other, manage to stay crammed together in the nucleus? Also, during their studies, scientists had come across a type of radioactive decay called 'beta decay' (see glossary). Beta decay was problematic as it seemed to violate the law of momentum conservation, which is one of the fundamental principles of physics. There must have been something else at work…

Going deeper

Back in 1909, physicist Theodor Wulf had shown that there were more charged particles than he expected at the top of the Eiffel Tower. This was ascribed to high-energy particles bombarding us from space – so-called cosmic rays. Scientists started using particle detectors at the tops of mountains, in hot air balloons or in aeroplanes to study these rays. Intriguing new particles began showing up which were not protons, neutrons or electrons, nor any combination of them. They called these particles 'hadrons' from the Greek meaning 'bulky' or 'thick', as they were generally much more massive than electrons. The lightest of the hadrons, the pion, was discovered in 1947. Many followed – a Greek alphabet soup of lambdas, rhos, sigmas and omegas. The large number of them was a worrying problem for anyone hoping for an elegant theory of fundamental physics.

Meanwhile, the beta decay problem was 'solved' by inventing a new, tiny, neutral particle – the neutrino. In 1930, theoretical physicist Wolfgang Pauli said, rather shamefacedly, "I have done a terrible thing, I have postulated a particle that cannot be detected." He was right about the

PHOTO: GETTY, SLAC X2



Neutrinos, as visualised in this computer simulation, are produced during beta decay

neutrino, but wrong about the impossibility of detection.

He wasn't the only one postulating new particles. In 1928, physicist Paul Dirac published his famous equation which unified quantum mechanics with Einstein's Special Relativity, and predicted that every particle should have an antimatter partner with exactly the same mass, but opposite charge. The positron – the antimatter counterpart of the electron – was discovered in cosmic ray observations four years later in 1932.

Back with the neutrino. In 1953, Frederick Reines and Clyde Cowan in South Carolina carried out an experiment that proved the neutrino was not just a figment of Pauli's imagination. They observed reactions caused by antineutrinos scattering off protons and producing positrons and neutrons. The chances of a neutrino, or antineutrino, actually interacting are very small. Despite the fact they placed their detector in an intense beam of neutrinos produced from the billions of interactions going on inside a nuclear reactor, they saw very few events – but enough to be conclusive.

The final pieces?

The detection of neutrinos was great progress, but the problem of 'too many hadrons' just got worse. But then, even tinier particles that make up the hadrons were postulated: quarks. Six different types of quark were revealed, starting in 1967 and ending with the discovery of the heaviest quark at Fermilab in Chicago in 1995. Quarks and electrons were enough to explain the matter content of atoms, and thus of all the elements.

But in parallel, physicists were developing an understanding of the forces responsible for holding atoms together. In the 1940s, Richard Feynman, Julian Schwinger and Sin-Itiro Tomonaga had developed 'quantum electrodynamics', a quantum theory of electromagnetism. Over a number of years in the 1970s, electromagnetism's equivalent for the strong force (which confines quarks inside hadrons) was also put together. This was known as 'quantum chromodynamics'. However, a third force, the weak force (responsible for beta decay) presented some problems.

Quantum electrodynamics and quantum chromodynamics both work because they are based on the symmetries of nature – aspects of physics that can be changed without altering the forces or the particles, in the same way that a square can be rotated by 90° and still look the same. Without these symmetries, the theories give nonsense answers. In the Standard Model, all the forces are carried by particles called bosons. But if you plug the symmetries into the equations of the Standard Model, it turns out that the particles which carry the forces have to be massless. This is fine for the carriers of the strong force (the gluon) and the electromagnetic force (the photon), but not for the weak force, which is carried by heavy, massive particles known as the W and Z bosons.

The solution exists in a theory developed in 1964 by Robert Brout, François Englert, Peter Higgs and others. They postulated a new energy field present everywhere in the Universe, and particles acquire mass by interacting with this field. In this way, the vital symmetry of the theory could be preserved, but the W, Z and other particles could have their observed mass. The theory also predicted a new, massive particle with zero charge. The Higgs boson, the missing piece of the Standard Model, was discovered at CERN's Large Hadron Collider in 2012.

But could there be another twist? According to their properties, the matter particles of the Standard Model are arranged in a pattern. There are six flavours of quark and six of leptons (see glossary), and they all come in three 'generations' of increasing mass. This is intriguing. Mendeleev gave us a huge clue to the substructure of atoms when he arranged the elements in the periodic table. The pattern of hadron properties was what led scientists to postulate the existence of quarks. Does the pattern of the Standard Model particles contain a clue to another layer of substructure, of even smaller things, that the quarks and leptons are themselves made of? We don't know. But with more scattering, and other experiments, we are trying to find out.



The Higgs boson was discovered at the Large Hadron Collider, pictured here with Peter Higgs himself

PHOTOS: GETTY, CERN

Prof Jon Butterworth is a University College London physics professor who works on the ATLAS experiment at the Large Hadron Collider.

DISCOVER MORE

BBC NEWS Watch an episode of *Click*, which explores the tunnels of CERN at **bbc.in/24gj51Y**

NEXT MONTH: UNDERSTAND DE-EXTINCTION



PHOTO: ISTOCK

Are we becoming more violent?

WITH THE CONFLICT IN SYRIA, TERRORIST ATTACKS IN FRANCE AND RACIAL TENSIONS IN THE USA, IT'S EASY TO THINK WE'RE BECOMING MORE VIOLENT. BUT DO THE STATS PAINT A DIFFERENT PICTURE?

WORDS: DR DAVID HAMMOND

David is a senior research fellow at the Institute for Economics and Peace. His research areas include the drivers of peace and conflict, terrorism and counter-terrorism, and assessment of state risk.

We are living in the most peaceful time in human history, at least according to the acclaimed book *The Better Angels Of Our Nature,* written by eminent psychologist Steven Pinker. Through analysis of historical estimates, Pinker details how common violence was in our past. Back then there were clans, witch trials and crusades to contend with. Today, evidence suggests that the developed world has never had to worry less about violence.

To account for this, Pinker describes the process of civilisation. The evolution of national governments allowed the emergence of fair and consistent trade.

But 9/11, the War on Terror and ongoing conflicts in Syria and Iraq demonstrate that violence is far from a bygone problem. The United Nations High Commissioner for Refugees (UNHCR) estimates that 65 million people are now forcibly displaced because of violence, which is the highest number since WWII. The Global Terrorism Index 2015 showed that deaths from terrorism have increased ninefold since the year 2000.

Conflict analyst Lewis Fry Richardson estimated that 1.6 per cent of people have died at the hands of another

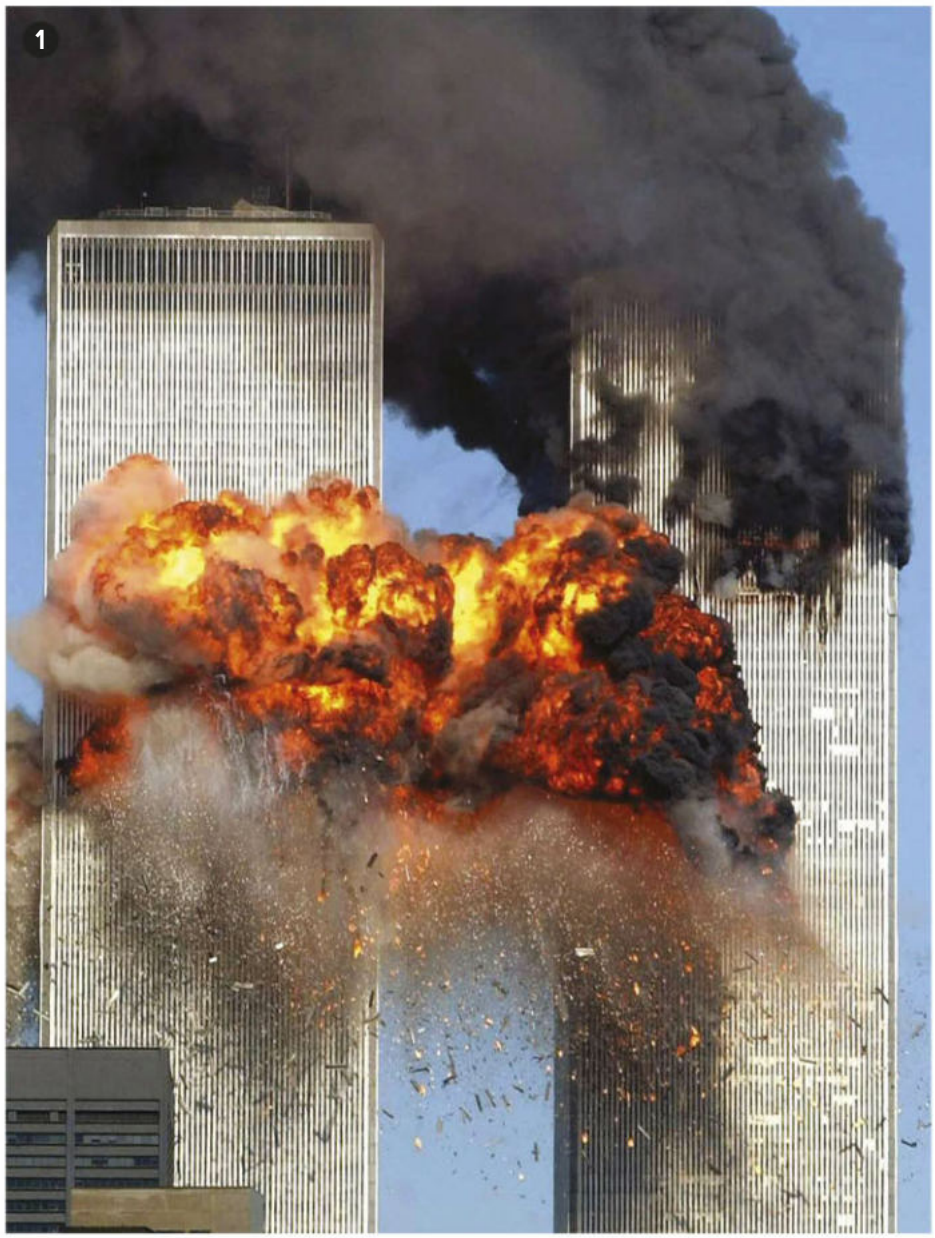
So this is the most peaceful time in history, yet there are also recent trends in violence. And it is this juxtaposition that leads to a surprisingly statistical debate.

MYTHS AND TRENDS

First, some good news: violence is rare. Lewis Fry Richardson, a Durham meteorologist turned conflict analyst, estimated that only 1.6 per cent of people died at the hands of another between 1820 and 1945. Sociologist Randall Collins suggests that, contrary to popular belief, humans generally do not find violence easy. Most bar fights end once one person makes contact with another and rarely escalate into the all-out brawls of Hollywood. In WWII it is estimated that as few as 15 to 25 per cent of soldiers actually fired upon the enemy when being fired upon themselves. Fear, it seems, became incapacitating. Many troops reported simply 'firing in the air' lest being branded a coward. In general, Collins suggests that people require intense social pressure to resort to violence at all. Furthermore, in an age where individualism is stronger than patriotism, armed forces are finding recruitment a challenge, and finding popular support for war is increasingly difficult.

Pinker's work demonstrates violence has declined in recent decades. Homicide rates, estimates of rape, domestic violence and even wars all appear to be falling. But a lot has happened since the publication of Pinker's book in 2011. The Global Peace Index, a measure of 23 indicators ranging from interpersonal violence to terrorism to international conflict, shows that the world is less peaceful than it was 10 years ago. Civil wars continue in Syria and Iraq. Terrorist attacks in Europe have increased since January 2015 when two brothers forced themselves into the offices of the French satirical paper *Charlie Hebdo*, killing 11 people with assault rifles. While homicide rates in the US have halved since 1995, mass shootings in 2015 killed 205 people, around five times as many than 2014. In the UK, violent crime has been on the increase since 2013 with reported hate crime increasing by 42 per cent after Brexit on 13 June 2016.

On an international level there are also ominous signs. The Doomsday Clock, which is compiled by the *Bulletin Of The Atomic Scientists*, estimates how close we are to global disaster from threats posed by climate change, deteriorating international relations and nuclear weapons. In 2015 the clock was set at three minutes to disaster, the worst assessment since 1984 when US and Russian relations were at their worst. And the list of instabilities that could be the prelude to an escalation of violence is long. The 2014 Russian annexation of Crimea and ongoing conflict in ▶



1 From a statistical angle, some analysts say terrorist attacks behave like earthquakes, with many smaller events leading to a catastrophic one like 9/11

2 Following the attack on French satirical paper *Charlie Hebdo* in early 2015, terrorism in Europe has increased

3 Modern conflicts tend to be domestic in nature, but are no less violent for citizens such as these pro-government fighters in Iraq

4 As of 2015, the Doomsday Clock has sat at three minutes to midnight, the closest to disaster since 1984







PHOTOS: GETTY X3, ALAMY



ABOVE: **During WWII, it is estimated that as few as 15 per cent of soldiers actually fired upon the enemy**

BELOW: **Modern drones can perform strikes remotely; could this make pulling the trigger easier?**



PHOTO: GETTY X2

Ukraine has tested post-Cold War relations, exacerbated by the shooting down of a Russian plane by Turkey in 2015. This year, over 52,000 people have been detained or arrested in the aftermath of the failed military coup that took place in Turkey on 15 July.

Elsewhere, on the 12 July, tensions heightened between China and the rest of the world after Beijing refused to accept the international tribunal in The Hague that ruled in favour of the Philippines in territorial disputes over the South China Sea.

THE STATISTICS OF VIOLENCE

To understand the arguments regarding whether we are becoming less violent, it is useful to consider a simple yet seemingly unrelated analogy: a sandpile. As sand falls it naturally forms a conical structure. Pour some more sand into the middle and it piles up higher and higher. Now imagine you add sand grains in a slow and controlled manner to a fully formed sandpile. Each grain falls and then comes to rest somewhere along the slope where friction balances gravity. This happens for many grains of sand, but eventually a single grain falls that causes one side of the pile to collapse, displacing a lot of sand in its wake. While simple, the forces and interactions taking place between the sand grains in the pile are difficult to model accurately and the effect of any single grain has to be treated as random.

On average, WWII killed as many individuals every seven weeks as we would expect today in one year of violence

First described in 1987 by the fathers of complexity theory, Per Bak, Chao Tang and Kurt Wiesenfeld, the randomness of the sandpile is strikingly similar to other phenomena. There are many grains of sand that have little effect but there is an occasional grain that has a major impact. In mathematical terms, this randomness can follow something called a 'power law'. Here, there are many small, low impact events and the occasional highly consequential event. In 2005, Aaron Clauset and Maxwell Young, computer scientists from the Santa Fe Institute, showed that terrorism followed the same statistical patterns of earthquakes, with many small attacks and infrequent but devastating events such as 9/11.

To illustrate, scale is useful. The United Nations Office of Drugs and Crime estimated that in 2012, almost 500,000 people were killed by homicide. The Global Terrorism Index shows that almost 33,000 people were killed by terrorism in 2014. According to the Uppsala Conflict Database, deaths from violent conflict in 2015 totalled 118,435. The World Health Organization estimates of 800,000 deaths by suicide every year. So, given the current global population of 7.4 billion, the mortality rate from all of these disparate forms of violence is around 20 people per 100,000. By contrast, WWII killed 60 million people in a worldwide population of 2.3 billion, an annual mean rate of over 435 people per 100,000. In absolute average terms, WWII killed as many individuals every seven weeks as we would expect today in one year of violence. When violence follows power laws, extremes need to be prioritised.

While patterns of violence provide interesting analogues with other phenomena, it is also disconcerting: in power laws it is not as unlikely to see an event bigger than the biggest on record. This is true for earthquakes, and may be true for violence.

But is violence really like earthquakes just because the numbers look alike? Philosopher John Gray is sceptical of the ability of statistics to capture the true nature of violence, as it's a topic that requires understanding of history, politics, economics, sociology and even psychology. While care certainly needs to be taken when interpreting statistics on violence, it is also true that the world is a complex system, and complex systems occasionally produce unpredictable results. Like the one grain of sand that causes an avalanche in the sandpile, no one could have predicted that Gavrilo Princip's opportunistic assassination of Archduke Franz Ferdinand would spark WWI.

But randomness doesn't mean that the odds can't change over time. So when it comes to violence, is there any evidence that the world is changing the odds toward peace?

THE LONG PEACE

The absence of large scale conflicts between superpowers in the post-WWII period has been described by eminent war historian John Gaddis as



Controversial presidential candidate Donald Trump has claimed that the UN, which promotes international cooperation, is ineffective

PHOTO: GETTY

the 'Long Peace'. The frequency of wars between countries has plummeted since 1945: the battles fought today are largely domestic in nature. Even today, nuclear weapons have only been used twice in warfare, despite tensions surrounding the Cold War. In a world in which military technology is capable of total annihilation of our species, humanity has so far managed to avoid Armageddon.

In light of this, in 2011 Pinker asked the obvious question: has something changed? There are clear developments in the post-WWII period that could account for the decline in violence. Democracy has continued to spread across the world. The emergence of the United Nations has offered new avenues of diplomacy and has enshrined the principle of sovereignty of state and borders. The use of chemical, biological and nuclear weapons have become an international taboo. The European Coal and Steel Community opened up markets for trade and eventually led to the European Union, offering an example of the benefits that come with regional integration. Meanwhile, across the Atlantic, civil rights movement represented a turning point in race relations in the US.

While recognising that the Long Peace may not be a perpetual peace, Pinker offers the theory that the post-WWII period has shifted from a game where countries conquer or be conquered, to a more cooperative system where war will only occur when the benefits outweigh the costs.

Donald Trump, running on a campaign of border protection, recently suggested that NATO is obsolete

JUST LUCK?

However, as many experts have pointed out, there may be alternate explanations for the data. For example, Tanisha Fazal, associate professor of political science and peace studies at Indiana's University of Notre Dame, highlights that the reason that fewer people are dying in wars may be because there have been advancements in medical treatments over the years. The Long Peace could also just be a run of luck in the power law nature of violence. In books such as *The Black Swan*, statistician and risk analyst Nassim Taleb has famously written extensively on the follies of projecting future trends from past data. In his work with probability expert Pasquale Cirillo, Taleb shows that the expected time between wars with at least five million casualties is 93 years. Taleb and Cirillo's work suggest that, when violence is dominated by extremes, it is too early to say with statistical confidence that the world has shifted towards peace only 71 years after WWII.

CURRENT CLIMATE

So is the fact that the world is less peaceful than it was 10 years ago a statistical fluctuation or something more serious? Well, almost 50 years after the civil rights movement in the US, the current Black Lives Matter protests show that tensions surrounding race issues remain. The EU project was dealt an unexpected blow with the Brexit referendum. In the current US presidential election, Donald Trump, running on a campaign of border protection, recently suggested that NATO is obsolete and that the UN was ineffective. The factors that Pinker ascribes as central to the Long Peace seem to be under attack.

But there are good reasons not to get despondent. In a 2013 interview, US politician Donald Rumsfeld explained a simple truth: "belief in the inevitability of conflict can become one of its main causes".

It is easy to focus on negatives, but the Global Peace Index shows that there is good news in the world. While wars continue, the most peaceful countries continue to become more and more peaceful. So it is fitting to finish this article with the insightful observation of Steven Pinker: "Instead of asking 'why is there war?' we might ask 'why is there peace?' We can obsess not just over what we have been doing wrong but also what we have been doing right".

There are undoubtedly challenges to face, but the post-WWII period has more than enough 'rights' to enable us to face them.

DISCOVER MORE

BBC RADIO 4 Listen to an episode of *The Life Scientific* with psychologist Steven Pinker at **bbc.in/2cMRhwR**

BBC ONE Watch an episode of *Panorama* about the Islamic State terrorist attacks in Europe at **bbc.in/2cetCai**



ROBERT MATTHEWS ON... PERSONALISED MEDICINE

"BY USING SMARTPHONE APPS, PATIENTS CAN RECORD THEIR PROGRESS WITHOUT SEEING THEIR DOCTOR"



According to new research, 'selfies' can help improve our dental hygiene. Apparently, people who video themselves while brushing their teeth, for later study by experts, are more likely to do it properly. Hardly a stunning revelation, you might think. But hang on – what is the 'proper' way to clean your teeth anyway?

According to the researchers, it's something called the Modified Bass Technique, which involves – well, I'm not going to bother explaining because here's the thing: it may not be the 'proper' way at all. The truth is, it's unclear what the best way is.

Researchers at University College London recently examined all the expert brushing advice they could find. They discovered a whole raft of claims, but precious little evidence backing them up.

To be fair, the team behind the 'selfie' study aren't claiming to have solved the problem of poor dental hygiene. Instead, they have highlighted yet another role for so-called mHealth – the use of mobile gadgetry in medicine. Fitness fanatics are leading the pack on this. They've been using wristband tech to check and record their performance for years.

But the wonderful thing about technology is that it typically gets ever more powerful but cheaper. And as that bang-for-buck ratio increases, what once seemed hopelessly sophisticated starts to look achievable.

That, in turn, could solve arguably the biggest medical problem facing the world today: finding out what works.

In these days of evidence-based medicine, that may sound odd. Surely we have reliable ways of finding out if a new therapy works? Indeed we do: wonder drugs are routinely tested using the 'gold standard' of medical evidence, the randomised controlled trial (RCT). This randomly allocates patients to receive either the new treatment or an alternative (the 'control'). After the allotted time, the two groups are compared to see which one fares better.

But there's a problem with RCTs. They're great for revealing what's likely to work with the average patient. The trouble is, that patient is very unusual.

The reason is simple: exactly how any one person responds to a therapy depends on a host of factors. How sick they are, what other health issues they have, their genes, gender, age, diet – the list just goes on and on.

The list is so long, in fact, that even if it is possible to define the average patient in any trial, the chance of any one person matching all those characteristics is tiny. And that's the problem doctors face every day. They have plenty of therapies proven to work for the 'average' patient. What they don't have is any insight into which one is most likely to work with the person they're treating.

There's a neat way to find out: set up an RCT for just that person. That is, randomly switch between the therapy and the alternative over set periods, and monitor how the patient responds.

Such 'N-of-1' trials are undoubtedly clever, but they are also potentially costly and time-consuming. And this is where smartphones and the like can help. By using apps, patients can record their progress without seeing their doctor. Specialist gadgets can also make measurements and transmit the outcome wirelessly.

Personalised medicine is one of the holy grails of 21st-Century science, and N-of-1 trials may be the fastest route towards it. They're now attracting a lot of interest among researchers. So the next time you're feeling poorly and you visit your doctor's surgery, don't be surprised if your GP asks about your health – and your smartphone.

Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest book *Chancing It: The Laws Of Chance And What They Mean For You* is out now (£14.99, Profile).

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Getting the party started with the KATCH couldn't be easier – Bluetooth 4.0 with Apt-X gives a wireless connection within seconds, while the NFC option is even quicker.

And keeping all options open, DALI has included a stereo mini-jack input, while the KATCH's USB charge connector means you can drive a Chromecast Audio dongle too, integrating your KATCH into your home network.

And keeping the party going isn't a problem, either, thanks to the KATCH's powerful 2600 mAh internal battery and power-level indicator lights; charging to full within 2-hours with the supplied charger, the KATCH then offers up to 24-hours of untethered playback.

Beautiful to behold, the KATCH is finished in an extruded aluminium body with ABS/polycarbonate front, complete with a sliding leather strap for easy carrying, plus a travel bag to keep the KATCH protected on the move. Who said brains and brawn don't go together?

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Q&A



DR CHRISTIAN JARRETT
Christian is a psychology and neuroscience writer. His latest book is *Great Myths Of The Brain*.



DR ALASTAIR GUNN
Alastair is an astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



PROF ROBERT MATTHEWS
Robert is a physicist and science writer. He's visiting professor in science at Aston University.



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Peter is a computer scientist and author who is based at University College London. His latest book is *Digitized*.



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Luis is a freelance science and tech writer with a BSc in computing and an MSc in zoology from Oxford University.



PROF MARK LORCH
Chemist and writer Mark is a professor at Hull University. He recently co-edited *A Flash Of Light*.

YOUR QUESTIONS ANSWERED

NOVEMBER 2016 | EDITED BY EMMA BAYLEY

Why do some trees grow crooked?

MILLY REES, LEICESTER

Trees normally try to grow with their trunk vertical, to provide the strongest support for their branches. But the Crooked Forest in Gryfino, Poland, has 400 pine trees, each with a 90° bend in their trunk. The trees were all planted in the 1930s, when Gryfino was part of Germany. After WWII, the native German populace was expelled and the town was resettled by Poles, so none of the locals know why the trees began growing like this. Various natural or accidental explanations have been proposed, including heavy snowfalls and damage from advancing German tanks. Yet none of them account for the very uniform bend, nor the perfectly normal pine trees growing right next to them. The most likely explanation is that they were deliberately bent to form curved timbers for furniture or ship-building. **LV**

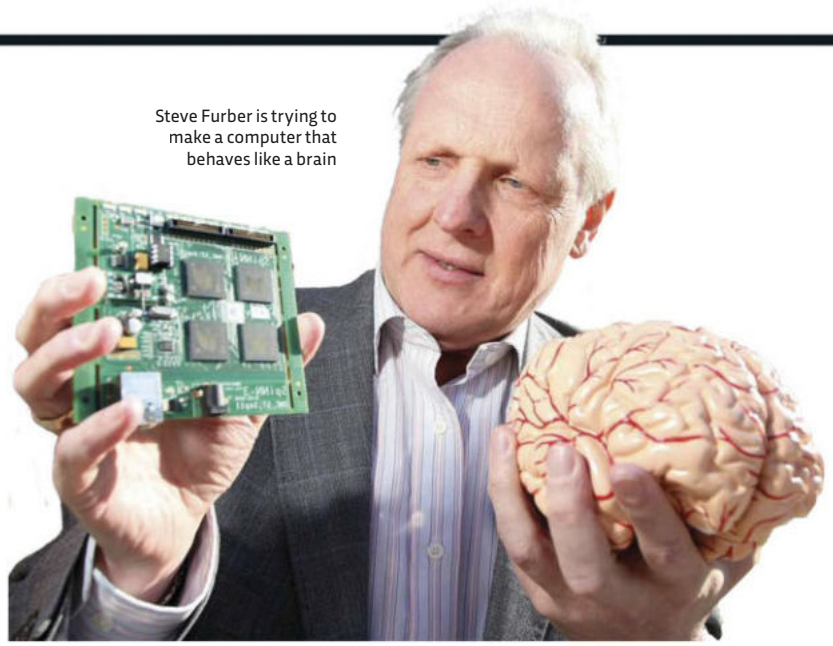
Nobody knows why the Crooked Forest's fairytale-like trees grow so strangely

Why do introverts find social situations so tiring?

KATE WARD, CANTERBURY

Apart from the simple fact that introverts prefer to have plenty of time to themselves, and that being denied this can be draining, there's also evidence that, at a physiological level, introverts respond more strongly to stimulation, such as loud noises, than extroverts do. This means socialising is more likely to leave them exhausted and needing a rest afterwards. On the *Introvert, Dear* blog, contributor Shawna Courter even argues that there's such a thing as an "introvert hangover", which she describes as "an actual physical reaction to [social] overstimulation. Your ears might ring, your eyes start to blur, and you feel like you're going to hyperventilate". **CJ**





Steve Furber is trying to make a computer that behaves like a brain

Could we create a biological supercomputer?

JOHN SCOTT, BROMLEY

There are some major research projects that are trying to build silicon computers that work like biological brains. For example, Steve Furber's SpiNNaker aims to make a supercomputer that can simulate one billion neurons. Some labs are also trying to make real wet biology behave like a computer.

Genetically engineered bacteria can be made to perform some basic calculations, and might one day be programmed to detect and treat inflammatory bowel disease or colon cancer. With billions of bacteria all computing in parallel, these would make a supercomputer in your own gut. **PB**

Can fish see in the dark?

ADAM CARLTON, YORK

It's not strictly 'seeing' but fish have rows of pressure-sensitive organs running down each side of their body called the lateral line, which allows them to sense nearby animals from the pressure changes in the water. Sharks and electric eels also have special sense organs that allow them to detect the tiny electric fields generated by other animals. LV

There's no need for deep-sea angler fish to have good eyesight



Why do joints crack?

STEVE SHAW, DURHAM

A 2015 study at the University of Alberta, Canada took real-time MRI images of finger joints as they cracked. The researchers found that as the surfaces of the cartilage pull away from each other, they create a site for a tiny bubble of dissolved gas (mostly CO_2) to form in the joint's lubricating fluid. The sudden expansion of the bubble creates the popping sound. **LV**

Why doesn't everyone get acne?

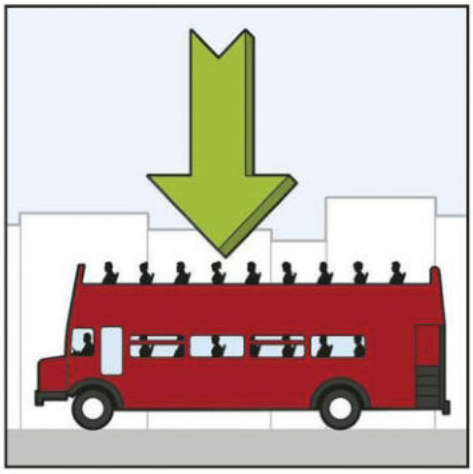
MELISSA THOMPSON, LONDON



Almost everybody experiences at least some acne during adolescence but severe acne, and acne that persists into your twenties and thirties, tends to run in families. How much sunshine you get or how much fatty food you eat doesn't make any difference. Whether the genetic link is because of oilier skin or different natural skin bacteria still isn't clear. **LV**

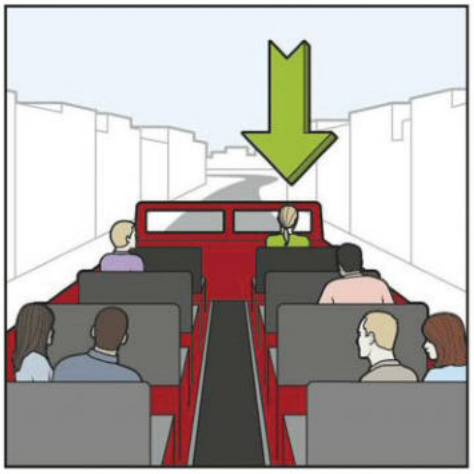
THE THOUGHT EXPERIMENT

WHERE'S THE BEST PLACE TO SIT ON A BUS TO AVOID TRAVEL SICKNESS?



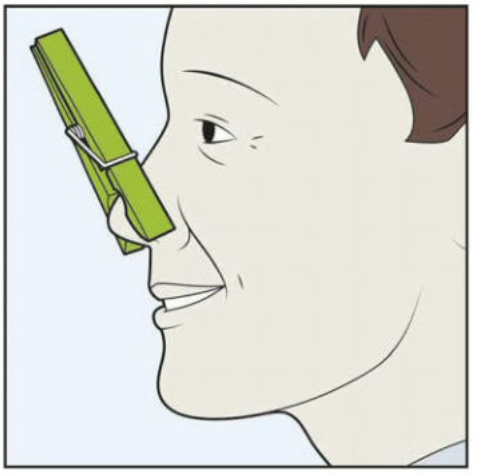
1. MINIMISE SWAYING

To avoid swaying, choose a seat close to the centre of gravity of the bus, midway between the front and back wheels. As the bus turns a corner, this point will travel in a smooth circle. That's better than the front or back, where you travel in a narrow ellipse that lurches round the bend at the start or end of the turn.



2. MAXIMISE THE VIEW

Looking straight ahead at the road is important to help your brain anticipate the movement of the bus and to keep the signals from your eyes and your inner ear synced up. The front seats on the top deck or an aisle seat on the left-hand side of the bottom deck are best for this.



3. MINIMISE SMELLS

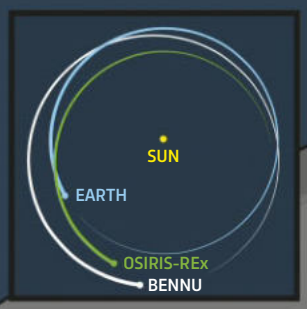
Your sense of smell is heightened when you are nauseous, which will make engine fumes and food smells even worse. Stay away from the back of the bus on the bottom deck and from anyone with a takeaway. Priority seats on the bottom deck are best. Second best is the top deck, three rows from the front, on the aisle seat.

PHOTOS: ALAMY X2 GETTY ILLUSTRATIONS: CHRIS PHILPOT

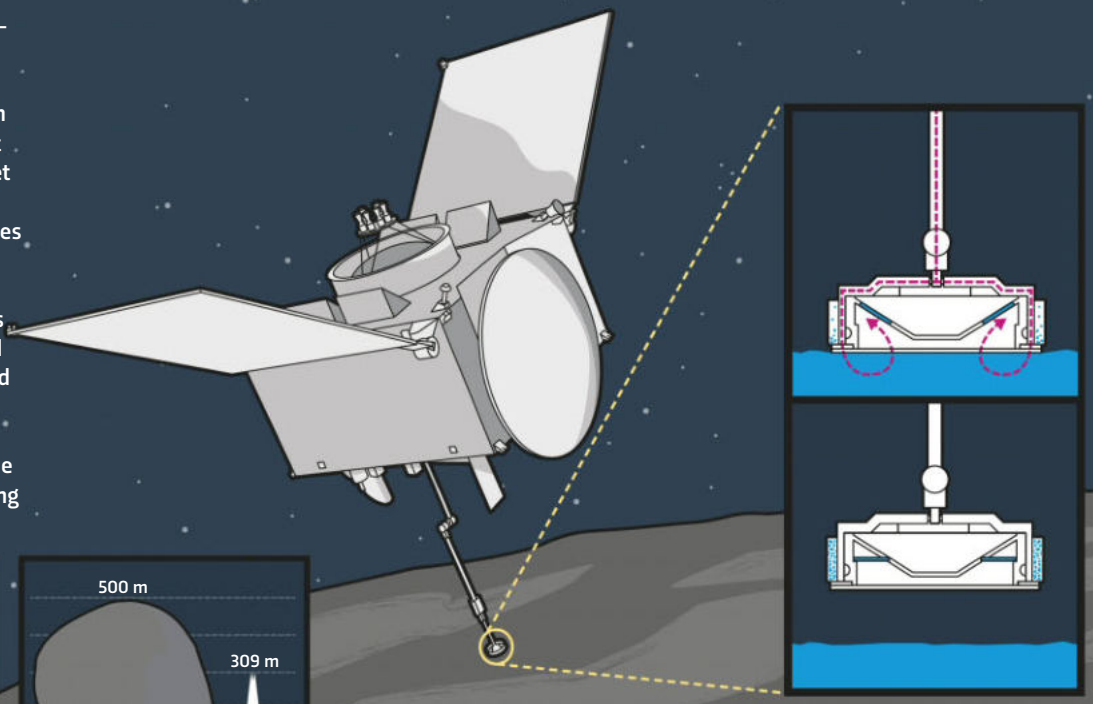
HOW IT WORKS

NASA'S OSIRIS-REx MISSION

On 8 September, NASA's OSIRIS-REx mission launched. It will spend a year orbiting the Sun, before travelling towards Earth on September 23 2017, where it will slingshot around the planet and start heading towards the asteroid Bennu. Bennu measures 500m in diameter and comes close to Earth every six years. OSIRIS-REx's arrival at Bennu is scheduled for August 2018, and it will start orbiting the asteroid in October that year, scanning and mapping the surface. In July 2020 it will gather a sample from the surface, before heading back to Earth.







To gather a sample from Bennu, a sampler head will be slowly lowered down to the asteroid's surface on a robotic arm. The head will fire nitrogen gas to blow regolith into the collection chamber. When enough has been gathered, the sampler head will be closed and safely stowed.



WILL THERE BE ANOTHER ICE AGE?

RANDALL BARFIELD, USA

Oddly enough, an Ice Age has gripped the Earth for most of the last 2.6 million years, and we're currently experiencing an unusually warm break from this so-called Quaternary glaciation, which temporarily lifted around 12,000 years ago. How long the ongoing 'interglacial' period will last depends partly on changes in the orbital size, shape and axial tilt of the Earth, and thus the intensity of sunlight, and also global warming – both natural and man-made. Earlier this year, a team at the Potsdam Institute for Climate Impact Research, Germany, published research suggesting a complex link between sunlight and atmospheric CO_2, leading to natural global warming. By itself, this will delay the next Ice Age by at least 50,000 years. Add in the effect of man-made global warming, and the delay is increased to 100,000 years. **RM**

How long does caffeine take to kick in?

BOB ELLIS, EDINBURGH



Studies have found that the effects of a cup of coffee or a glass of cola are noticeable after just 10 minutes, but the peak caffeine concentration in the blood occurs after 45 minutes. If you take the same caffeine dose in tablet form, the peak caffeine level will be the same but it takes longer – between 60 and 75 minutes – to reach that peak.

For most people, the caffeine level in your body halves roughly every six hours. So 50 per cent of the caffeine from your 4pm cuppa is still circulating in your system at bedtime. **LV**

PHOTOS: GETTY X6 ILLUSTRATION: CHRIS PHILPOT



"Can you smell blood?"

How do sharks smell blood underwater?

TODD MICHAEL WILSON, USA

When you smell something in the air, it's because scent molecules have dissolved into the wet lining of your nose. Smelling underwater is no different, except that the molecules are already dissolved in the seawater. It's a myth that sharks can smell a single drop of blood from a mile away.

Sharks actually have roughly the same sensitivity as other fish and can detect smells at between one part per 25 million and one part per 10 billion, depending on the chemical, and the species of shark. At the top end, that's about one drop of blood in a small swimming pool. **LV**

IN NUMBERS

1,200

The number of cheetah cubs illegally trafficked out of Africa over the last decade. Just 15 per cent survived the journey.

7 million

The amount of egg cells present in a 20-week-old female foetus, decreasing to about a million at birth.

1.5

The wingspan, in metres, of a relatively tiny Late Cretaceous pterosaur that was recently unearthed in British Columbia.



A seal brain a day keeps the doctor away

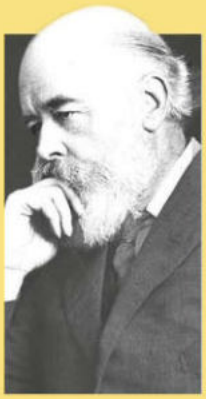
How do Inuits get their five-a-day?

ANNE BARKER, COLCHESTER

The traditional Inuit diet does include some berries, seaweed and plants, but a carnivorous diet can supply all the essential nutrients, *provided* you eat the whole animal, and eat it raw. Whale skin and seal brain both contain vitamin C, for example. But an Inuit diet isn't any healthier than a modern Western diet. Inuits have similar levels of coronary heart disease and a somewhat higher incidence of osteoporosis and stroke, since they get a higher proportion of their calories from animal fat and have limited access to dietary calcium. **LV**

WHO REALLY DISCOVERED?

RADIO



OLIVER LODGE



GUGLIELMO MARCONI

The discovery of radio waves ranks among the most astounding achievements of Victorian science, with far-reaching consequences that are still felt today.

Their existence was predicted in the 1860s by the brilliant Scottish theoretical physicist James Clerk Maxwell, while he was developing a theory that revealed electricity and magnetism are just different aspects of the same phenomenon.

Maxwell's prediction was confirmed in 1887 by the German physicist Heinrich Hertz, who – incredibly – dismissed radio waves as "of no use whatsoever". Fortunately, other scientists saw potential in the mysterious waves that could travel through air, solid walls or the vacuum of space. Among them were the British physicist Oliver Lodge and the Italian electrical engineer Guglielmo Marconi, who independently invented ways of turning electrical discharges into detectable signals. The two men were often locked in legal battles over patents, but Marconi is usually regarded as the 'inventor' of radio communication. That's partly because he was the first to send simple radio signals across the Atlantic Ocean, a PR coup which led to international recognition, including a Nobel Prize.

Yet even Marconi failed to realise the full communication potential of radio. The technical challenges of going beyond electric sparks to a high-fidelity speech and music medium needed the work of a host of far less well-known inventors. RM

10 OF THE SMALLEST MAMMALS



1. *Batodonoides vanhouteni* (extinct)
Weight: 1.3g
Distribution: North America



2. Kitti's hog-nosed bat
Weight: 1.5g
Distribution: Thailand and Myanmar



3. Etruscan shrew
Weight: 1.8g
Distribution: Southern Europe to South Asia



4= Pygmy jerboa (smallest rodent)
Weight: 3g
Distribution: Pakistan and Afghanistan



5= African pygmy mouse (smallest rodent)
Weight: 3g
Distribution: Sub-Saharan Africa



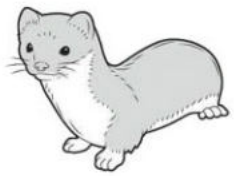
6. Long-tailed planigale (smallest marsupial)
Weight: 4.3g
Distribution: Australia



7. American shrew mole
Weight: 10g
Distribution: Northwestern USA



8. Pygmy possum
Weight: 10g
Distribution: Australia, Papua New Guinea, Indonesia



9. Least weasel (smallest carnivore)
Weight: 29.5g
Distribution: Northern hemisphere



10. Madam Berthe's mouse lemur (smallest primate)
Weight: 30g
Distribution: Madagascar



Was the Baghdad Battery really a battery?

EDWARD SEYMOUR, HOVE

Found in 1938 by a German archaeologist, the 'Baghdad Battery' could be 2,000 years old, and consists of a clay jar, a copper cylinder and an iron rod. If filled with a weak acid, like vinegar, the combination produces around 1 volt. Yet while even some experts refer to it as a battery, its true origin and purpose remains unclear. One idea is that it was used for electroplating objects with precious metals. **RM**

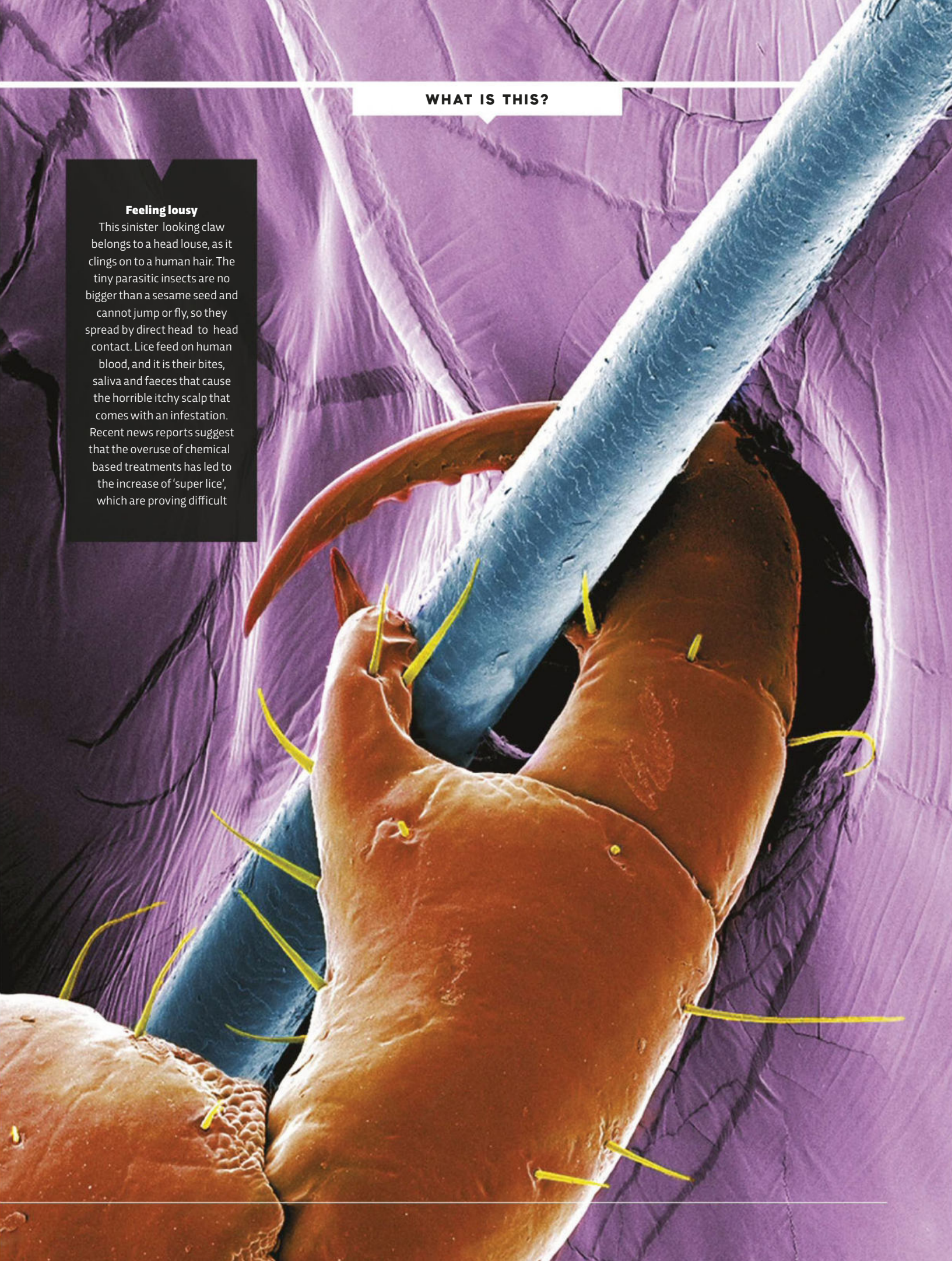
Who owns the Moon?

FINN BOGDAN, SWITZERLAND



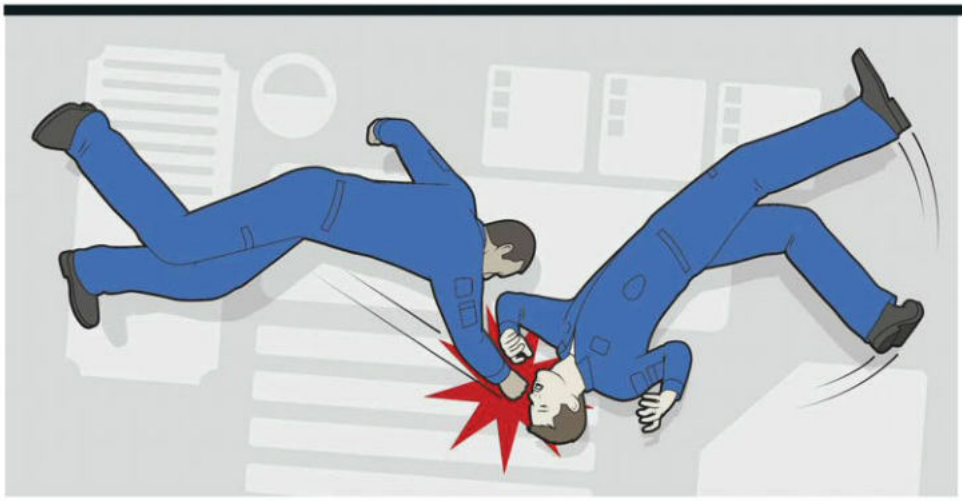
Officially, nobody. The issue of owning extraterrestrial space or objects is governed by the United Nations' Outer Space Treaty, first enacted in 1967. It forms the basis of international space law. Article II of the treaty states "outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." Some entrepreneurs have argued that this doesn't apply to private individuals and they are therefore free to claim (and sell off) portions of outer space, including lunar real-estate! However, legal bigwigs insist that nations take responsibility for not only state and corporate functions but also private citizens. There is also a legal concept called *corpus possessionis* which implies that for something to be 'owned' it must be 'controlled' – something not possible unless an individual can access and defend their lunar real-estate. In reality, anyone buying a piece of the Moon owns nothing more than an expensive bit of paper. **AG**

PHOTOS: SCIENCE PHOTO LIBRARY, GETTY XS, ALAMY, SCIENCE PHOTO LIBRARY, NATUREPL.COM, MICHIGAN STATE UNIVERSITY



Feeling lousy

This sinister looking claw belongs to a head louse, as it clings on to a human hair. The tiny parasitic insects are no bigger than a sesame seed and cannot jump or fly, so they spread by direct head to head contact. Lice feed on human blood, and it is their bites, saliva and faeces that cause the horrible itchy scalp that comes with an infestation. Recent news reports suggest that the overuse of chemical based treatments has led to the increase of 'super lice', which are proving difficult



Would a fist fight hurt less in microgravity?

BETHANY RAMSHAW, NEWCASTLE

The first punch might, because the assailant can't brace against the ground, so some of the momentum of his fist will be wasted pushing his body backwards. But once the two brawlers are pushed in opposite directions to the walls of their spacecraft, they will be able to launch themselves back again. The second punch will be boosted by the forward momentum of the astronauts as they sail together, and it will hit even harder. **LV**

Why does thunderstorm rain contain more nitrogen than ordinary rain?

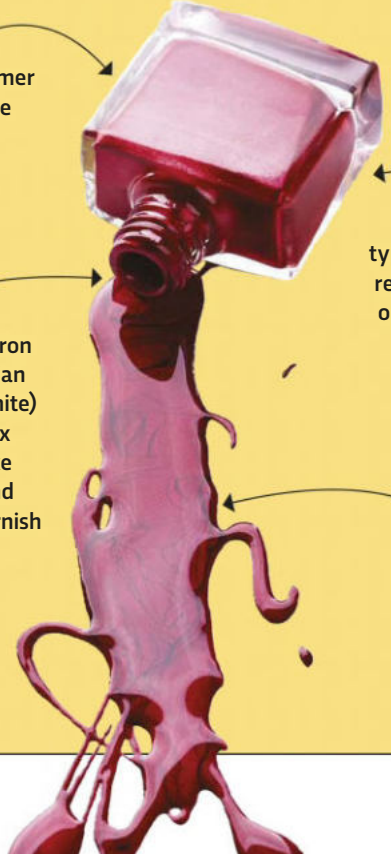
PETER BOOTH, NEW ZEALAND

Air is 78 per cent nitrogen, and plants need it to grow. Nitrogen gas is chemically very stable because it is made from two atoms that form strong bonds with one another. Breaking these bonds requires lots of energy before they can react. Lightning can provide this energy, breaking the bonds and leaving the free nitrogen atoms to combine with oxygen in the atmosphere. The resulting compounds are called nitrates, which dissolve in rainwater more readily than nitrogen gas. Most plants cannot use nitrogen gas but they can use nitrates. Because of this, thunderstorm rain is particularly good for fertilising plants. **ML**

WHAT'S IN...

...NAIL VARNISH

Nail varnish generally consists of three main components: polymer molecules form the film that's deposited on your nails, dyes provide the colour, and everything is dissolved in solvents that quickly evaporate after the varnish is applied.

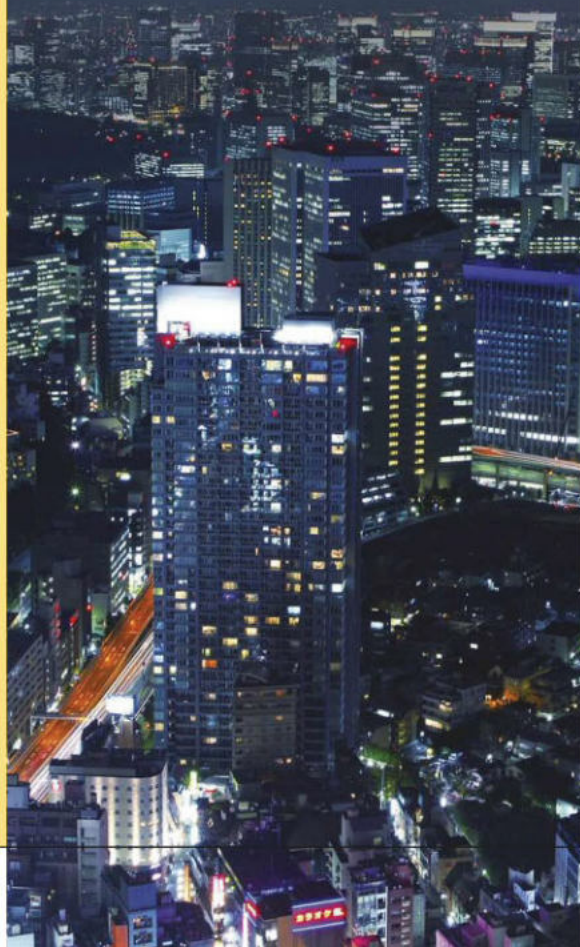


POLYMERS
Nitrocellulose is the polymer molecule that forms the lacquer left on nails.

SOLVENT
Butyl or ethyl acetate are typically used as the solvents, replacing acetone which was once popular in nail varnish.

DYES
Chromium oxide (green), iron hexacyanoferrate (Prussian blue), titanium dioxide (white) and much more complex chemicals known as 'lake pigments' act as dyes and pigments providing the varnish with its colour.

GLITTER
If your varnish has a bit of glitter or shimmer then it might include mica or aluminium powder.





Zeus was having a really bad day



Is the Internet of Things real?

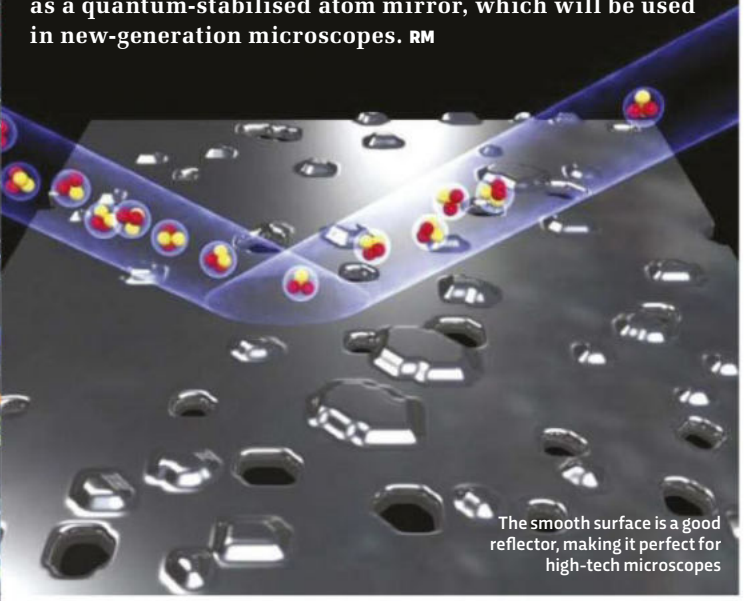
PETE HANBURY, MANCHESTER

The internet is made from a vast global collection of computer networks that all interconnect. In contrast, the Internet of Things (also known as 'ubiquitous computing') is a set of smart devices that connect to the internet, making them accessible remotely. Today we have connected heating thermostats, security cameras, motion sensors, lights, doorbells and even toasters. By 2020 it's estimated there will be more than 20 billion connected devices. While this may give us amazing access to information and computing from smart objects all around us, some people warn that our privacy may be reduced because every device could be monitoring us. **PB**

What's the smoothest known material?

JACK CATALANO, USA

In 2011 a team of physicists in Spain created a perfectly smooth material by coating a thin silicon crystal with a layer of lead a dozen or so atoms thick. According to the team, quantum forces between the atoms levelled out even atom-sized bumps. The result was a surface known as a quantum-stabilised atom mirror, which will be used in new-generation microscopes. RM



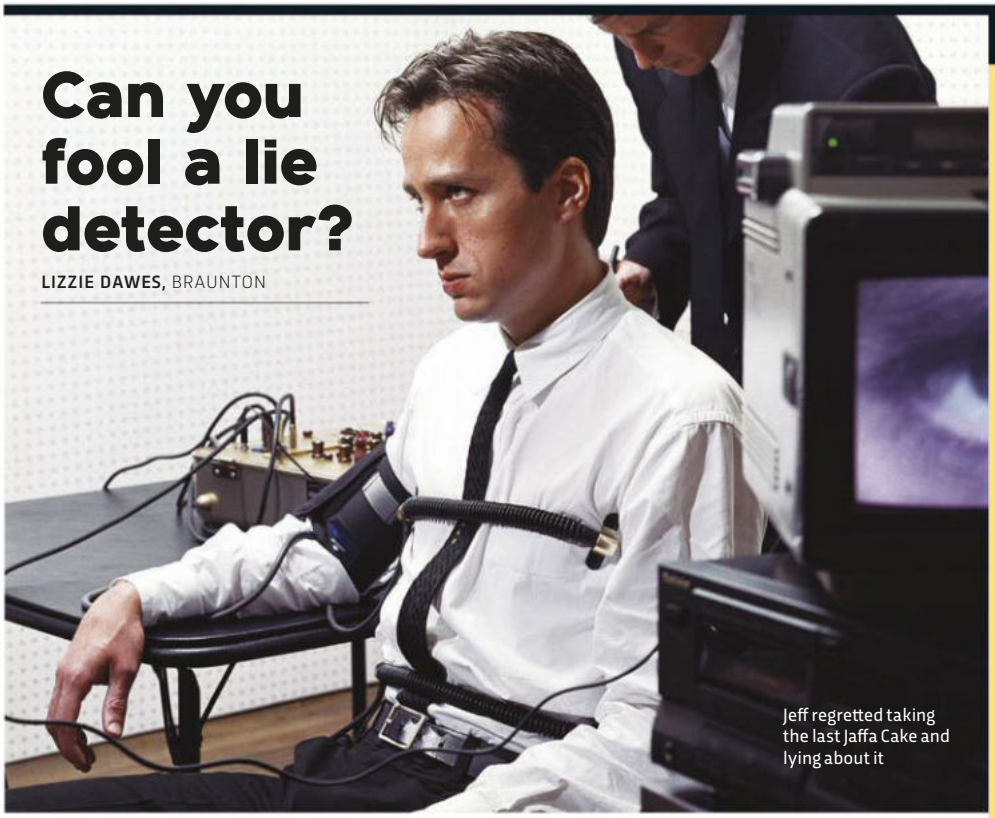
The smooth surface is a good reflector, making it perfect for high-tech microscopes

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PHOTOS: ISTOCK X2, ALAMY, ILLUSTRATION: CHRIS PHILPOT

Can you fool a lie detector?

LIZZIE DAWES, BRAUNTON



Jeff regretted taking the last Jaffa Cake and lying about it

The polygraph test, still used widely in the US, measures your heart rate, breathing and blood pressure as a way to tell how stressed you are feeling. The idea is that the interrogator asks you questions and when you lie, you get more stressed than when you tell the truth, and this difference is revealed in the physiological measures. A simple way to cheat the polygraph is to deliberately distort your physiological readings when telling the truth, such as by biting your tongue, or imagining an embarrassing incident in the past. Similar problems afflict brain scan lie detectors, which follow the same principle of needing a reliable baseline against which to compare signs of lying. **CJ**

Do all substances have three states of matter?

CAROLINE ALLISON, KING'S LYNN

Far from it: many substances can be found in more than three states of matter, while others have fewer than three. All the chemical elements can be induced to form solids, liquids or gases. But if you superheat a gas, then the electrons get stripped away from the nuclei to form plasma. Stars are made from plasma, so it is in fact the most common state of matter in the Universe. Other more complex materials will decompose before changing states. For example, if you heat wood then it will burn rather than melt. Even if you heated wood in a vacuum, then it would break down into simpler substances before changing state. ML



Not all substances exist in three states of matter

WHAT CONNECTS...

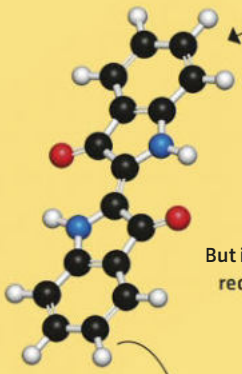
...MUMMIES AND PRINTERS?



1. Ancient Egyptian mummies have been found with linen wraps, dyed a deep blue. This colour has survived for thousands of years when all other dyes have faded away.



2. The dye comes from the plant *Isatis tinctoria*, commonly known as woad. Originally native to Asia, it has been cultivated in Europe since the Roman period at least.



3. The dye molecule is indigo, which is normally insoluble in water and doesn't stick well to fabric. But it can be chemically reduced to the soluble and colourless white indigo.



4. White indigo has been used in ink for inkjet printers. This soluble form doesn't clog the printer nozzle but it converts back to blue indigo on contact with the oxygen in the air.

PHOTOS: GETTY X4, SCIENCE PHOTO LIBRARY, CHRIS FOSTER/UNIVERSITY OF MANCHESTER



What would happen to Earth's orbit if the Sun vanished?

PETER CAMERON-BURNETT, DEVON

If the Sun miraculously disappeared, the Earth (and all the other objects in the Solar System) would continue their forward motion in a straight line off into space, instead of following their almost-circular orbits. For the Earth this means it would head off towards the stars at about 30km/s (67,000mph). There may be some subsequent interaction between the planets of the former Solar System, but otherwise we'd continue floating through space probably without ever encountering another object. Even if we did, we'd be long dead, having frozen to death within weeks of the Sun's disappearance! AG

QUESTION OF THE MONTH

Can a human produce a sound outside the human audible range?

ANDREW DALTON-GILL, BRANSGORE

The hearing range of nearly all mammals is wider than the frequency range they can produce with their voices. This is because the top end of our hearing range has evolved to help us accurately detect the direction of a sound. The ear facing away from the sound hears less of the higher frequencies because they are absorbed by your skull.

The human ear can hear frequencies up to 20kHz but we can't scream higher than 3kHz or so. The bottom end of our hearing range is 20Hz, which is still just below the deepest notes that most of us normally make (around 85Hz). But a few individuals have managed to go much deeper. The world's deepest voice belongs to US singer Tim Storms, who can sing a note at 0.189Hz, or eight octaves below the lowest G note on piano! A note this low can't be heard, only felt. **LV**

WINNER!
Andrew Dalton-Gill wins a Sphero SPRK+(£99, **sphero.com**). This cute waterproof robot, along with its app, makes learning the basics of coding fun and accessible.



NEXT ISSUE:
What time is it on the Moon?
Are left-handers smarter?
Does chicken soup help a cold?

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ROBIN INCE ON... GHOSTS

"GHOSTS CAN BE EXPLAINED BY PREVALENT MYTHS, HALLUCINATIONS AND OUR PATTERN-SEEKING MINDS"

Even before The Smiths instructed me, I had been hanging around cemeteries. As I'm not as happy-go-lucky and gregarious as Morrissey, I usually went alone. Sadly, I never caught sight of a ghost, but my sceptical view of these spirits has never dampened my delight in a good ghost story. On the few occasions I foolhardily walk through woodland in the dead of night, I'm unhelpfully reminded of what horrors may lie in the bristling undergrowth.

In an early series of *The Infinite Monkey Cage*, we asked why people believe in ghosts. Possible explanations included auditory and visual hallucinations, the influence of the prevalent myths we are brought up with, and the ability of our pattern-seeking minds to create phantoms from half-glimpsed shadows. During the broadcast, we were hexed by three witches, and we also received a complaint that we had a biased panel as there were no members of the undead.

So what else can science say about ghosts? In 2001, Richard Wiseman, Professor of the Public Understanding of Psychology at the University of Hertfordshire, sent volunteers into the famously haunted vaults under Edinburgh's South Bridge. The volunteers were unaware of which parts had the strongest reputation for ghostliness, but afterwards, Wiseman found that particular areas were consistently rated as more 'haunted'. His explanation? The environmental factors. The spookier rooms were larger, had higher ceilings and had more lighting in the corridor directly outside the vault. Wiseman believes that this created an increased sense of vulnerability and darkness inside these vaults. Or maybe it's just that ghosts are tall and need a lot of headroom.

Could infrasound vibrations also be to blame? In the 1990s, Coventry University researcher Vic Tandy worked in a lab where staff often felt a sense of a 'presence' in certain areas. One night, he experienced a grey, indistinct apparition in the periphery of his vision. After eliminating other possibilities, he found the cause: an extraction fan, sending out inaudible, low-frequency sound waves at around 19Hz – roughly the same as the resonant frequency of the eyeball. This resonance could cause smeared vision, explaining the shadowy illusions experienced by the lab workers. The ghosts disappeared when the fan was turned off.

Our brains, it seems, are primed to see spirits. One of the most recent examples involved a robotic arm. Prof Olaf Blanke at Switzerland's École Polytechnique Fédérale de Lausanne wanted to build an experiment to recreate the sense of a foreign body. Participants moved their index finger in front of their body, while a robotic arm reproduced the movements on their back. The volunteers felt as if they were touching their own back, but when the robotic arm was very slightly out of sync, the mind couldn't make logical sense of the experience, and they felt as if they were being watched. Two volunteers were so spooked by the sensation that they opted out. Having an out-of-sync sense of ourselves can lead to us creating a second presence, easily imagined as a ghost. If it's not caused by a robotic arm, this could be triggered by exhaustion or disease. Human imagination is flamboyant: we should enjoy it, but be wary of it, too.

Once, I worked with the wonderfully eccentric actor Sarah Miles. On hearing that I knew Richard Dawkins, she wondered if I could share his contact details as she knew a cottage so haunted that she wanted to leave him there overnight, believing this would overturn many of his suppositions. I wonder if she ever managed to tie him down – that's an episode of *Most Haunted* I'd love to watch.

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*
bbc.in/1Lxp3QR

NEXT ISSUE: CHRISTMAS SHOPPING

ILLUSTRATION: JAMIE COE

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

NOVEMBER 2016 | EDITED BY JAMES LLOYD



01

PLANET EARTH II
BBC ONE FROM
6 NOVEMBER.

GET EXCITED ABOUT *PLANET EARTH II*

Ten years ago, Planet Earth wowed us with its spine-tingling photography and heart-in-mouth sequences, setting a new precedent for natural history film-making. Now it's back, and it looks set to be Sir David Attenborough's most impressive series yet.

Using the latest in camera and drone technology, Planet Earth II takes us through six habitats, from jungles, deserts and mountains to islands, grasslands and cities. The snow leopard (pictured) promises to be one of the stars of the show. These notoriously elusive animals, which roam the mountains of central and southern Asia, are listed as endangered, with as few as 4,000 individuals remaining in the wild. Undeterred, the *Planet Earth II* team developed a new generation of remote camera traps to film the snow leopards up-close like never before. We can't wait to see the results.

PHOTO: BBC/DAVID WILLIS





02 LEARN HOW TO SURVIVE ON MARS

HOW TO SURVIVE ON MARS
STARTS ON 24 OCTOBER FOR FOUR WEEKS
FUTURELEARN.COM/COURSES/SURVIVE-MARS

If Matt Damon's character had taken this online course, *The Martian* would have been over a lot sooner. Created by Monash University in Australia, How To Survive On Mars will teach you the basic science you'd need to live on the Red Planet. From the comfort of your home, learn how to produce oxygen, water, food and energy on an inhospitable world, and how to cope with intense radiation and extreme temperatures. Covering chemistry, biology, physics and geology, the 12-hour course will give your grey matter a workout even if you're not planning a Martian holiday any time soon.

03 RELIVE THE FIRST NIGHT OF TV

TELEVISION'S OPENING NIGHT: HOW THE BOX WAS BORN
IS ON BBC FOUR IN EARLY NOVEMBER.

Once upon a time, there was no such thing as television. Hard to imagine, we know, but 2 November 1936 was the date of the very first official (and completely live) BBC broadcast.

Unfortunately, there are no surviving recordings of this momentous occasion. So, to mark the 80th anniversary, this one-off programme attempts to recreate the night that British television was born. Dallas Campbell is joined by engineers Prof Danielle George and Dr Hugh Hunt to resurrect the original technology and filming techniques, including John Logie Baird's 'flying spot' – a seven-foot-tall mechanical monster that featured a steel disc spinning at almost the speed of sound.

As for the broadcast itself, expect enough singing, tap dancing and contortionism to give *Strictly* a run for its money.



04 EXPLORE THE VIRTUAL WORLD

This month, the Oculus Rift and PlayStation VR hit the shelves. Here are six VR experiences that you should try first…

1 COMMAND A *STAR TREK* SHIP

STAR TREK: BRIDGE CREW (OCULUS RIFT, HTC VIVE, PSVR)

Team up with your friends to crew the USS Aegis and explore an uncharted region of space. The captain gets to shout "shields up", the engineer can use a VR motion controller to actually do it, while the tactical officer flings photon torpedoes at the Klingons off the starboard bow.

ubisoft.com/en-GB/game/star-trek-bridge-crew

2 VISIT A VR THEME PARK

THE VOID, US LOCATIONS

In this 'hyper-real' experience, participants wear a haptic feedback vest and head-mounted display as they wander around physical sets, the visuals and audio syncing with their real-world actions. The Void's main location will be in Utah, with franchises around the US such as the recently opened *Ghostbusters: Dimension* in NYC. Here's hoping for one in the UK…

3 BECOME BATMAN

BATMAN: ARKHAM VR (PSVR)

Access the Batcave, don your Batsuit and do some Batforensics at a crime scene in this superhero sim. The problem of motion sickness in VR is smartly addressed by teleportation-style movement, while the game's slow-paced, investigative nature really plays to VR's strengths.

playstation.com/en-gb/games/batman-arkham-vr-ps4

4 ENTER FAIRYTALE LAND

ALLUMETTE (OCULUS RIFT, HTC VIVE, PSVR)

Loosely based on Hans Christian Andersen's story *The Little Match Girl*, this beautiful offering from Penrose Studios falls somewhere between film and game. It's not truly interactive, but you do feel as though you're present in the floating city as you position yourself to watch the tiny protagonist.

penrosestudios.com

5 SCALE NEW HEIGHTS

THE CLIMB (OCULUS RIFT)

Hold on to your stomach! *The Climb* puts you in the shoes of a rock climber, looking for the tiniest hand- and footholds as you scale sheer precipices. Race your friends to the top and admire the view when you get there – but whatever you do, don't let go!

theclimbgame.com

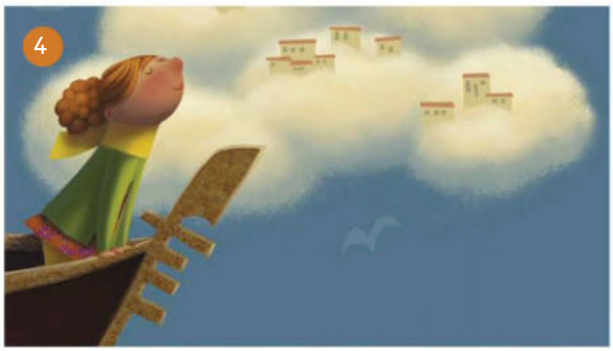
6 LAND ON THE MOON

APOLLO 11 VR EXPERIENCE (OCULUS RIFT, HTC VIVE, PSVR)

An interactive documentary about the momentous events of July 1969. You can relive Neil Armstrong and Buzz Aldrin's giant steps, explore the Moon's surface and, if you're feeling daring, take the controls of the Eagle lander unit as it touches down in the Sea of Tranquility.

immersivevreducation.com/the-apollo-11-experience/













PHOTOS: MONASH UNIVERSITY, BBC



05 MAKE A MESS

Papers all over your desk? Bedroom a shambles? In his new book *Messy*, economist TIM HARFORD explains why you might just be doing it right after all

MESSY
BY TIM HARFORD
IS OUT ON 3 NOVEMBER (£20, ABACUS).

When is it good to be messy?
We like the idea of tidiness, but a lot of the things that we value such as creativity, responsiveness, and spontaneity come from mess – messy teams, messy processes, messy desks.

One example is mess in the workplace. A psychologist called Steve Whittaker studied how people work, comparing 'pilers' (those who keep piles of paper on their desk) to 'filers' (those who prefer an organised system). He found that the filers tended to prematurely file stuff away, leading to filing cabinets full of dross. With the pilers, on the other hand, the useless stuff naturally sank to the bottom of the pile and eventually got thrown out. They were managing their archives much more efficiently and getting more stuff done.

How else can messiness help?
It can work in a more metaphorical sense, too. Cognitive psychologists have shown that when we're interrupted, distracted or encounter an obstacle, it can provoke creative thinking. So if you're putting together a presentation or searching for the solution to a scientific problem, a bit of 'messy' randomness can free your mind and help you to solve the problem.

Improvisation is another powerful way in which we can turn mess to our advantage. In creative environments, improvising helps us to be more responsive and listen better, and in the workplace it creates much more engaging presentations.

The same is true for politics. Martin Luther King improvised the climactic second half of his "I have a dream" speech, and Donald Trump won the Republican nomination through being able to improvise. His speeches and public appearances weren't that great, but he was able to keep wrong-footing his opponents by changing what he said and what he did. It seemed like a joke, but no one had a response.

Can messiness go too far?
Absolutely. In the wrong situations, mess can be totally dysfunctional. You can be improvising with no structure or preparation; you can have a desk that's creaking under the strain of junk. There are lots of places where order is important, but mess is underrated. We hardly ever think it's the appropriate approach, and we don't give it enough of a chance. We all think, "If only I could get tidier, I'd get more done." But I don't think we would – life is messy, and we should embrace that.

How can we introduce some messiness into our lives?
My first tip would be to let paper accumulate on your desk – it's a very effective sorting mechanism. Secondly, force yourself into areas where you're uncomfortable, whether that's meeting new people, trying a new activity or visiting an unfamiliar place. And thirdly, if you're feeling overwhelmed by stuff, consider just throwing a lot of it away. If there's too much stuff, there's too much stuff, and you're often better off simplifying rather than trying to impose a system.

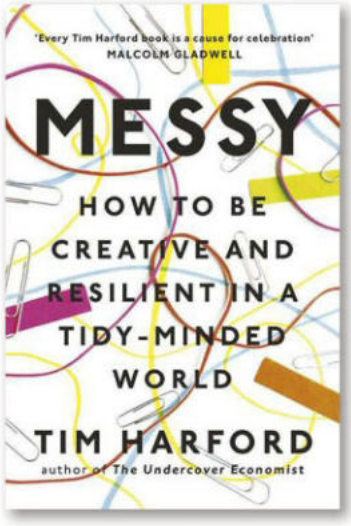


PHOTO: GETTY

ELLEN SCHAGERSTRÖM REVEALS HER FAVOURITE SPOTS IN **STOCKHOLM**



Stockholm is beautiful, with a spectacular blend of architecture, history and water. It's large enough to contain all one needs, but small enough so that a cab home in the early hours won't cost an arm and a leg. I like the city best in the mornings, preferably a summer Sunday, biking over the bridges and watching the sunshine clear away the fog from the water.

I've got loads of favourite museums. The **NATIONAL MUSEUM OF SCIENCE AND TECHNOLOGY** ❶ is full of cool gadgets. I occasionally borrow friends' children just to have an excuse to go crazy on the kids' stuff! But when I've had a frustrating day in the lab, I head to **THE NOBEL MUSEUM** ❷. Walking around it gives a sense that even great scientists fail, but that some of these failures can lead to new breakthroughs.

I love visiting Stockholm's botanical garden, **BERGIANSKA TRÄDGÅRDEN** ❸, which is a wonderful oasis on the banks of the Baltic Sea. The director is known as 'Professor Bergianus', a post which was most recently held by Birgitta Bremer, whose vast work in taxonomy and systematics led to parts of the garden being redesigned. She is an amazing botanist, who I admire a lot. On a cold day, I take my lunch in the Victorian waterlily house. The Aquaria Water Museum is another good place to go in winter, as it's warm and makes me think of the tropics far, far away.

One of my favourite restaurants is **NALLE & KROPPKAKAN** ❹, which serves old Swedish cuisine, including 'kroppkaka' – the Swedish take on the German 'knödel' dumplings.

SJÄTTE TUNNAN ❺ is a great medieval-style restaurant down in the cellar of one of the 15th-Century houses in the Old Town. The place is a bit touristy, but they also have a bar at street level. Linus the bartender is amazing – whenever I go in there, he'll ask me how my day's been and, based on my reply, he'll serve me what he feels is needed.

There is a restaurant, Louis, that does live jazz every day. I once heard the lead singer announce "Now for something modern – this song is from 1943!" And, like many Stockholmers, I love lunching at the hot dog kiosk **GÜNTER'S KORVAR** ❻. It's known to many Swedes through the crime novels of Leif GW Persson. Join the crowd! Ⓕ

ILLUSTRATION: TONWEN JONES

❶ **NATIONAL MUSEUM OF SCIENCE AND TECHNOLOGY**
Sweden's largest museum of technology.
Museivägen 7
tekniskamuseet.se

❷ **NOBEL MUSEUM**
This museum tells the story of the Nobel Prize, its founder, and its laureates.
Stortorget 2
nobelmuseum.se

❸ **BERGIANSKA TRÄDGÅRDEN**
Beautiful botanical gardens on Brunnsviken Bay.
Gustafsborgsvägen 4
bergianska.se

❹ **NALLE & KROPPKAKAN**
A restaurant serving Swedish cuisine in the hipster area of Midsommarkransen.
Svandammsvägen 41
nalleokroppkakan.se

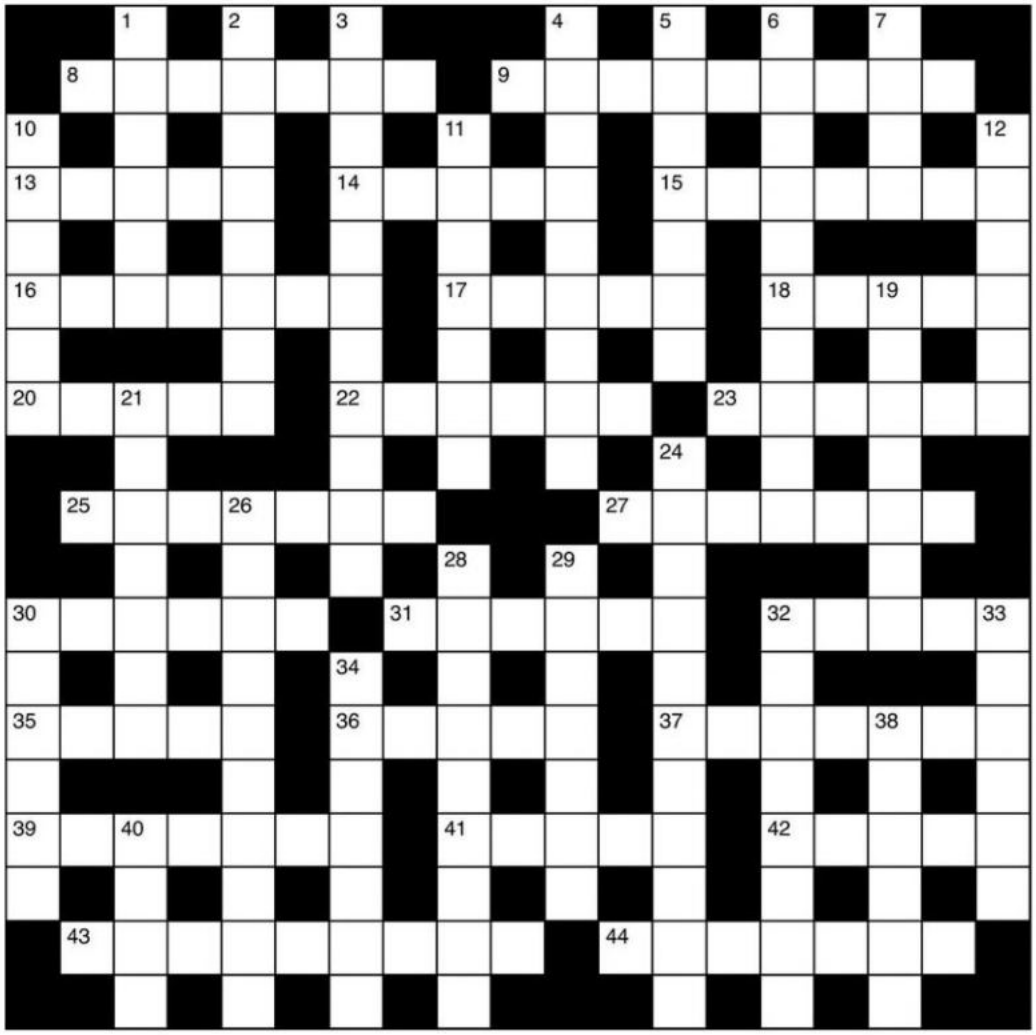
❺ **SJÄTTE TUNNAN**
Medieval food is on the menu, including wild boar meatballs and elderflower cheesecake.
Stora Nygatan 43
sjattetunnan.se

❻ **GÜNTER'S KORVAR**
Hot dog joint serving sausages from around the world.
Karlbergsvägen 66
bit.ly/2cdjVuG

Ellen Schagerström is a marine ecological botanist, researching seaweed at Stockholm University. She blogs at **balticseaweed.com**



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ACROSS

8 Atom is too affected by exercise (7)
9 Leading runner needs cardiac device (9)
13 Husky, say, or another animal (5)
14 European agreement on 11 days between years (5)
15 Rise awkwardly, owing what's left (7)
16 Betting article stimulates his tongue (7)
17 Husband lost out to man of the planets (5)
18 Youngster to object to length (5)
20 Shoot to school with puritan (5)
22 Fashionable to enjoy old colour (6)
23 Force staff to get a loading device (6)
25 Flavouring in a strange ovule (7)
27 40 mixture Ian managed to get into snack (7)
30 Sylvester holds English record for being somnolent (6)
31 Shop account (6)
32 Principle of reversibility (5)
35 Credit university – or a blood clot (5)
36 Fool concerning explosive matter (5)
37 Listener treats each pain (7)
39 Same costume (7)
41 Body part generating argon (5)
42 Children's edition (5)
43 Carried on cooking herb (9)
44 Bird having celestial fun (7)

DOWN

1 His trial took place around peninsula (6)
2 Anglo-Saxon prince to lighten a performance (8)
3 Nuclear physicist upset hemp pioneer (11)
4 Gristle trail led off into enclosure (9)
5 Fellow takes queen to ceremony in compound (7)
6 Series of devices worn round the neck, childishly (5,5)
7 Reportedly perceived some cattle (4)
10 Monkey considered a bloody factor (6)
11 Heat cod – recipe is terminal (7)
12 Chap has pint nowadays with group of seven (6)
19 Building new toy inside old instrument (7)
21 Working on a rude poem (7)
24 Serpent to upset traitor (11)
26 Copper coins spent very fast (10)
28 Does retry to scupper ship (9)
29 Medication to get into shape (7)
30 Pouch with strange bone (6)
32 Work behind hill to get a piece of bread (8)
33 Heard two characters in temporary accommodation (6)
34 Mean to cultivate single plant (7)
38 Affair at navy billet (6)
40 Press club (4)

ANSWERS

Please visit **bit.ly/TheNumberGames** for the answers to this month's puzzles and crossword.

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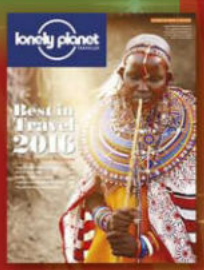
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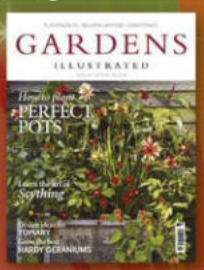
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NEXT MONTH



DECEMBER ISSUE ON SALE 11 NOVEMBER

NEUROSCIENCE

Secrets of the teenage brain

The latest neuroimaging techniques are helping us to understand why teenagers behave in the way they do. It turns out it's not their fault, and it never was.

NATURE

PLANET EARTH II

As the long-awaited follow up to 2006's *Planet Earth* hits our screens, we look into some of the incredible wildlife stories at the heart of Sir David Attenborough's new series.

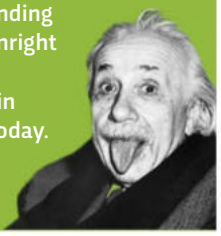


PHOTOS: GETTY X3, BBC

WEIRD THEORIES

THE 10 STRANGEST IDEAS IN SCIENCE

From our lost sixth sense to the Sun's hidden twin, we delve into the most mind-bending and downright bizarre theories in science today.



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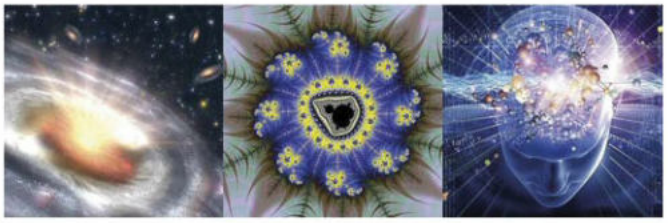
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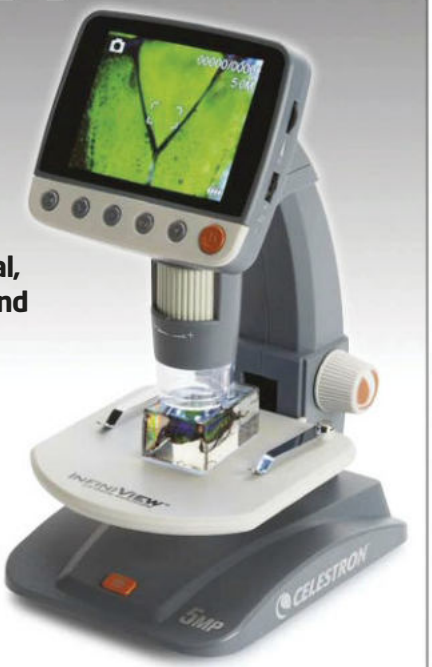


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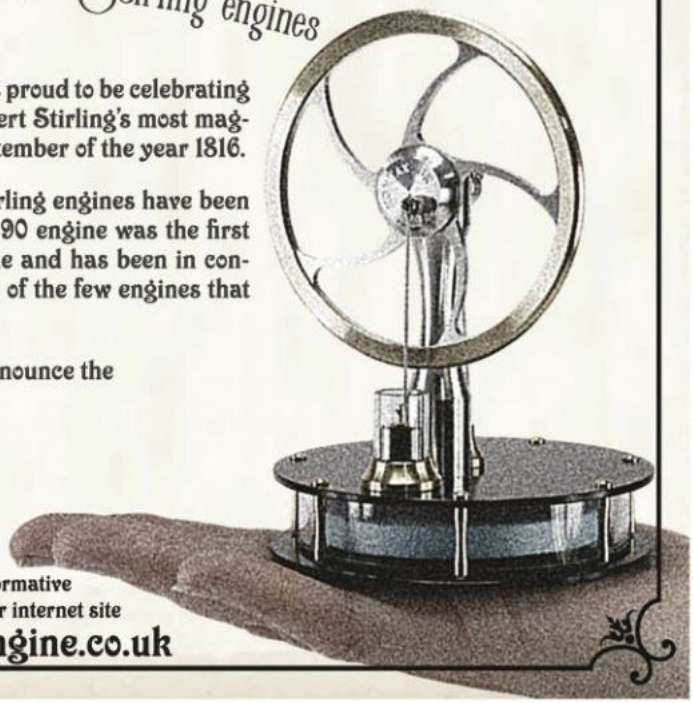
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Dr Peter Lovatt

"I believe we are born to dance and that it's innate. There's no culture anywhere in the world where dancing doesn't happen"

Strictly Come Dancing is back! **Helen Pilcher** talks to **Peter Lovatt**, aka 'Dr Dance', about music, movement and the importance of finding your groove



I'm interested in how dance can change the way people feel, think and solve problems. I run the Dance Psychology Lab at the University of Hertfordshire where we research the psychology of dance.

I have a little boogie every day. I believe we are born to dance and that it's innate. There's no culture anywhere in the world where dancing doesn't happen.

Two-day-old babies can perceive rhythm. At five months old, they begin to respond physically to music. Then, at two-and-a-half years old, they can entrain their movements to a beat. It starts to looks like dancing.

Dancing has so many positive effects. We've shown that when people learn a set dance routine, they get faster at solving 'one solution' problems, such as long division. But when they do improvised dance, their creative problem solving improves. Other people have found similar results in non-lab settings, like the classroom. We worry that if kids fidget, all the clever stuff will spill out of their heads. But research suggests the opposite. If you let children stand up or stretch while they are in the classroom, it can help the learning process.

We've shown how improvised dance can help people with Parkinson's disease. It can enhance mood and ease symptoms. The effects can be quite profound and long-lasting.

I used to be a professional dancer. I toured nationally, did panto with Anita Dobson and even spent six months working as a dancer on a Caribbean cruise ship. There's a photo of me shaking my maracas and wearing tights. It was every bit as flamboyant as an episode of *Strictly*.

Whenever I give talks, I always get people up on their feet grooving. I recently did an event on neural synchronisation where I got the audience to wriggle around in an uncoordinated way to represent the way neurons work. Then, every now and then, I'd get groups of people to move together, like clusters of neurons firing. We had this whole brain flash mob thing going on. I've done quite a bit of TV too. I was on *Big Brother's Bit On The Side* where I represented the personality of various housemates through the medium of dance. And I've been on *Strictly Come Dancing: It Takes Two*. I watched rehearsal tapes and was asked to predict who would go furthest in the competition. I did pretty well.

I dance because it makes me happy. People have lots of different motives to dance. It can be for social reasons, or for fitness. It can be the challenge of learning something new, or a form of cathartic release. For me, it feels like the most natural activity to do. I couldn't imagine life without it.

The thing that fills me with joy is combining my passion for dance with my love of science. It makes me very, very happy.

Dr Peter Lovatt is a dance psychologist at the University of Hertfordshire.

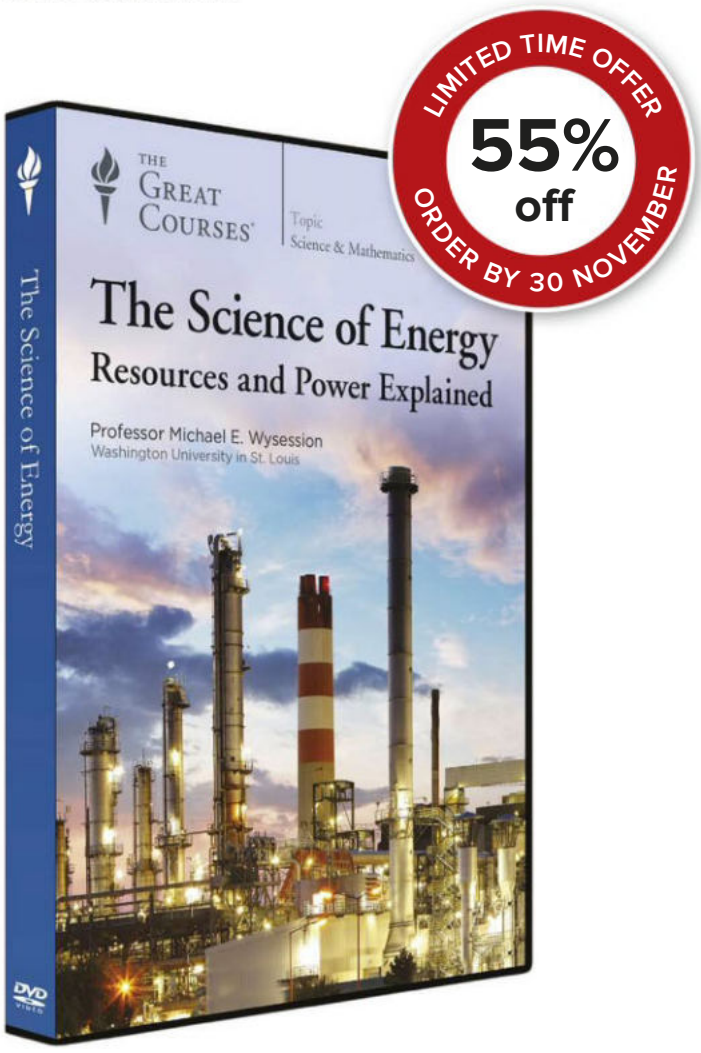
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